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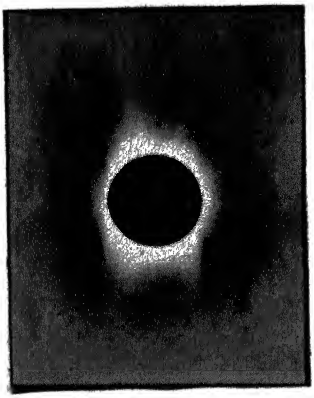

REPORTS ON THE OBSERVATIONS

OF THE

TOTAL ECLIPSE OF THE SUN

OF

JANUARY 1, 1889

PUBLISHED BY

THE LICK OBSERVATORY.

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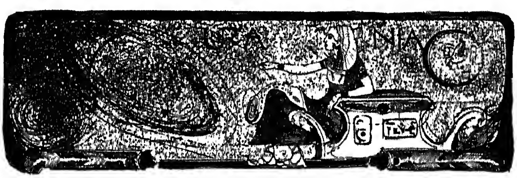

TOTAL SOLAR ECLIPSE OF JANUARY, 1889.

INTRODUCTION.

By Edward S. Holden.

In the summer of 1888, the Regents of the University of California authorized the publication of a pamphlet of "Suggestions for observing the Total Eclipse of the Sun on January 1, 1889." This was accordingly prepared at the Lick Observatory by myself, with the assistance of Messrs. Burnham and Schaeberle, and was widely distributed throughout California, especially in the region of total eclipse. It was expected that some eclipse expeditions might be sent to California from Europe, and to provide for the wants of European and other observers I prepared a short paper on the meteorological conditions to be expected at the time of the eclipse, on the facilities for transportation of eclipse instruments, etc., which was printed in the *Monthly Notices of the Royal Astronomical Society*, volume 48. Copies of this pamphlet were sent to astronomers who were contemplating a journey to California with the intention of making observations of the eclipse.

Many letters of inquiry from intending observers were received at the Lick Observatory, and these were promptly answered. They usually related to choice of an observing station, to methods and means of observation, to facilities for transportation, etc. A number of members of the Amateur Photographic Association of the Pacific Coast made a visit to the Observatory for the purpose of consulting with the astronomers here regarding photographic observations. Their visit resulted in the formation of an eclipse expedition by members of the Association, under the energetic direction of Mr. Charles Burckhalter (of the Chabot Observatory). The very successful work of this expedition is detailed in Part III. of this Report. The excellent plan of operations adopted, and the skill and devotion of the members of this large party, are well exhibited in their several reports. One of the incidental benefits of the close and cordial coöperation of professional and amateur observers has been the formation of the

Astronomical Society of the Pacific, which is intended to perpetuate this close association both as a scientific and as a social force.

The Lick Observatory time-signals were sent to all railway stations in and near the line of totality at noon of December 30 and 31, and of January 1 and 2. We are indebted to F. L. VANDENBURGH, Esq., Superintendent of Telegraphs of the Southern Pacific Company, for his interest and aid in this regard.

I copy from the *Astronomical Journal*, vol. VIII, page 168, a note by Mr. SCHAEBERLE on the corrections of the transmitting clock for these days: December 30, $= + 0^s.98$; December 31, $= + 0^s.35$; January 1, $= - 0^s.18$; January 2, $= + 0^s.01$. The latitude and longitude of the observing station at Norman, occupied by the eclipse expedition of the Washington University Observatory party (St. Louis), was determined, at the request of Professor H. S. PRITCHETT, Chief of Party, by Mr. J. E. KEELER, of the Lick Observatory, in February, 1889, and the results are given in Part II.

The pamphlet of *Suggestions to Observers* before referred to, contained sections relating to Observations of Contacts; Observations near the Limits of the Shadow; Spectroscopic Observations; Meteorological Observations; Drawings of the Corona; Special Phenomena; and to Photography. The latter section recited the necessary precautions to be taken, and gave instructions relating to the vital question of the proper times for exposure, which were written by Mr. BURNHAM of the Observatory, as the result of experiments by himself on photographs of light clouds near the sun, etc., taken in conditions somewhat similar to those of the Coronal Streamers at an eclipse. The general success of the photographs secured by those observers who followed the *Suggestions* is, in great measure, due to the principles here clearly laid down (so far as I know, for the first time).

The recommendation of extremely short times was founded on sound theoretical ideas, checked by experiments, and has resulted in undoubted success. The photographs of the present eclipse surpass all others, so far as I know, in delicacy of detail, and in extent of the outer coronal wings.

Many expeditions from Observatories outside of the State were sent to California. The most thoroughly equipped of these expeditions were from Harvard College Observatory; from the Washington University Observatory, of St. Louis; from the Carlton

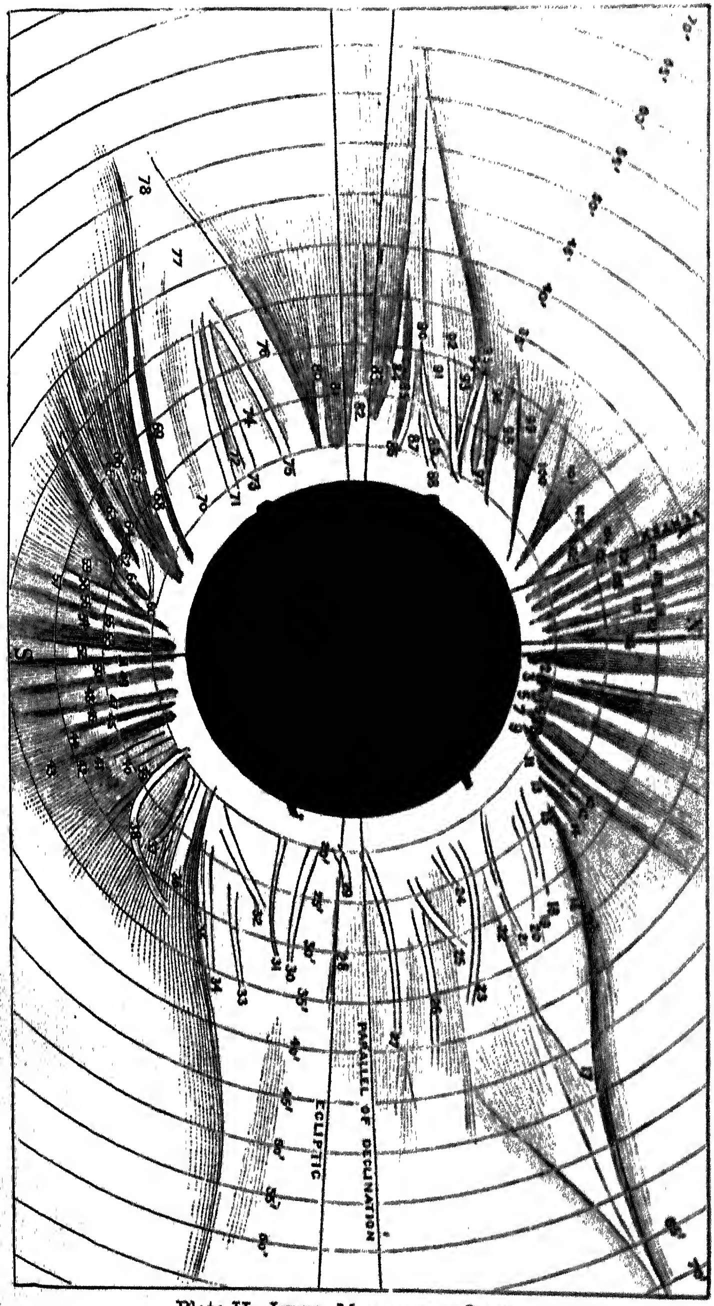

Plate II; Index Map of the Corona.

College Observatory, Northfield, etc. A large number of observations by amateurs have been transmitted to Professor D. P. Todd, of Amherst College, in answer to instructions and requests sent out by him. The present report, together with the reports of the parties above mentioned, will probably contain most of the work of importance upon this eclipse.

Diagrams of the Solar Corona, from Photographs by E. E. Barnard, of the Lick Observatory, and from Photographs by Messrs. Ireland and Lowden, of San Francisco.

From the beautiful photographs of Mr. Barnard, I have prepared the diagram, or index map of the Corona, which is given in Plate II. One of Mr. Barnard's negatives was first copied in positive on glass, and a projection from this positive was thrown on a screen by a lantern. From this projection a careful drawing (Moon's diameter equal to 2⅝ inches) was made. The positive was then examined by the transmitted light of a kerosene lamp through an opal glass shade under a magnifying glass, and the outlines obtained by projection were filled in. The parallel of declination, ecliptic, and vertex were then inserted from computations by Mr. Keeler. The sun's axis is inclined 1° 24′ to the N. and S. line as drawn.

It is necessary to say that in making this diagram no pictorial effect has been sought for. It was intended to show only the more important features and details exhibited in the negatives obtained by the Lick Observatory party. The fainter details shown in the diagram are, necessarily, relatively too plain. A number of the minor features are omitted to avoid confusing the drawing, and because they were not well seen on account of the small size of the original negatives (Moon's diameter equal to $\frac{44}{100}$ inches). The principal features are numbered for convenience of reference, from 1 to 113. Near the lines extending from the centre of the Sun towards the East and West, I have placed a scale of minutes of arc, corresponding to the faint circles described about the Moon's centre. The diagram is least satisfactory in the region 35 to 38. I have to thank the Council of the Royal Astronomical Society for the gift of the capital cut (Plate II), as well as for the illustrations of the photographs of Messrs Ireland and Lowden (figure 1).

We may say *a priori* that the phenomenon of the Sun's Corona is composed of at least three superposed appearances. There

must be, *first*, some coronal effect due to diffraction, etc., at the Moon's limb (this probably is of small amount); *secondly*, we have polar rays at the North and South poles of the Sun; and, *thirdly*, we have the equatorial wings or extensions, and rays or striations connected with them. These are what are called "groups of synclinal structure" by Mr. RANYARD in Memoirs R. A. S., vol. 41, p. 486. If we divide the phenomenon into parts by reference to brightness alone, and not simply as to structure, we have the inner Corona (which is bright) and the outer Corona (which is faint).

Taking the Corona as a whole, the first great result of the eclipse of 1889 is that *the characteristic coronal forms vary periodically as the Sun spots (and the Auroras) vary in frequency.*

Even a casual comparison of the drawings and photographs of 1889 with those of previous eclipses occurring at a period of minimum Sun spots (the eclipses of 1867 and of 1878) shows that the characteristic forms of 1889 are typical of an epoch of minimum spots. The type for maximum spotted area is equally characteristic and very different. While there are minor features that vary from eclipse to eclipse and do not follow this law closely, it appears that, broadly speaking, the eclipse of 1889 has established the correctness of the law above given, so far as our present data are sufficient. I believe that this law was first pointed out as probable by Mr. RANYARD. (*Memoirs Royal Astronomical Society, vol. 41, 1879.*)

We can best describe the parts of the Corona, as to extent and structure, by a reference to the index map. The map shows the outer coronal wing at the S.E. extending as far as (78) or 55′ from the Moon's centre. At the N.W. it extends, fairly bright, to (17) or 50′, and it can be traced to the 75′ circle by looking obliquely at the negatives, or by slowly moving them before a bright lamp with a porcelain shade. The S.W. wing extends to the 50′ circle as fairly bright, and can be traced to 60′. The N.E. ray or wing can be traced to 55′. All the important polar rays extend as much as 25′ to 30′ from the Moon's centre, and the longest ray (2) attains a length of 36′ in Mr. BARNARD's best negative. There is no great amount of detail (except the four hydrogen flames) to be seen between the Moon's limb and the 20′ circle. It will be noticed that the S.W. protuberance is in two distinct parts. A few of the narrow dark polar rifts (1, 3, 5, 7, 9, 43, 45, 47, 49, 51, 53, 57, 67, 69, 99, 101, 102–103, etc.) end within the 20′ circle. The bright ring immediately around the Moon's limb may be, in a small degree,

due to the chromosphere, but it seems likely that a certain portion of it, at least, is due to diffraction, and most of it is a purely photographic defect. The inner Corona ceases to be bright at about 25′ in general, and in the wings, 17, 30, 77, 92, the brightness falls off rapidly beyond the 30′ circle.

Extension of the Outer Corona.

A very curious feature of the best photographs is that the coronal wings on the W. side (20, 30) seem to have their north and south edges (16, 34,) roughly parallel as far out as 45′ or 50′; while at this distance the edges (16–17, 34) begin to diverge towards N. and S., respectively, into a trumpet-like form. If the photographs are attentively considered, they appear to show that the coronal beams inside the 50′ circle are gradually concentrating themselves. This seems to be their law as far as this point. It is therefore surprising to find at the 55′ circle the strongly marked tendency to divergent forms and to a trumpet-like extension. If the negatives did not show any portions of the wings beyond 45′ or 50′, it would be at once concluded from them that their extensions were convergent, as has, indeed, been concluded from photographs of previous eclipses. But from the 50′ circle outward to 65′ and 75′ (on the west side of the Sun) the lines (16–17), (34) become strongly divergent, so that at the 65′ circle their distance apart (N. and S.) is already something like 45′.

When I first discovered this in Mr. Barnard's negatives, I was inclined to doubt the positions of the faint edges (16–17), (34), which I had laid down from his photographs, and I therefore sought for some further evidence from the many drawings which had been sent to the Observatory for discussion.

The drawings of Miss Robertson at Cloverdale, Mr. Staples at Bartlett Springs, Miss Silvia Rey at Cloverdale, Miss Nellie Treat at Cloverdale, Mr. C. Mason Kinne at Cloverdale, clearly indicate something of the trumpet-like extension referred to on the west side of the Corona. The sketch of Miss Treat shows an extension of the south edge of the S.W. wing extending to 89′ from the Moon's centre. These drawings were all made without hiding the inner Corona from the eye.

The drawing of Miss Treat in particular agreed beautifully in direction with the line (34) of the photographs. The divergent character of the coronal wings on the West side of the Sun is completely proved by the photographs and by the drawing referred to,

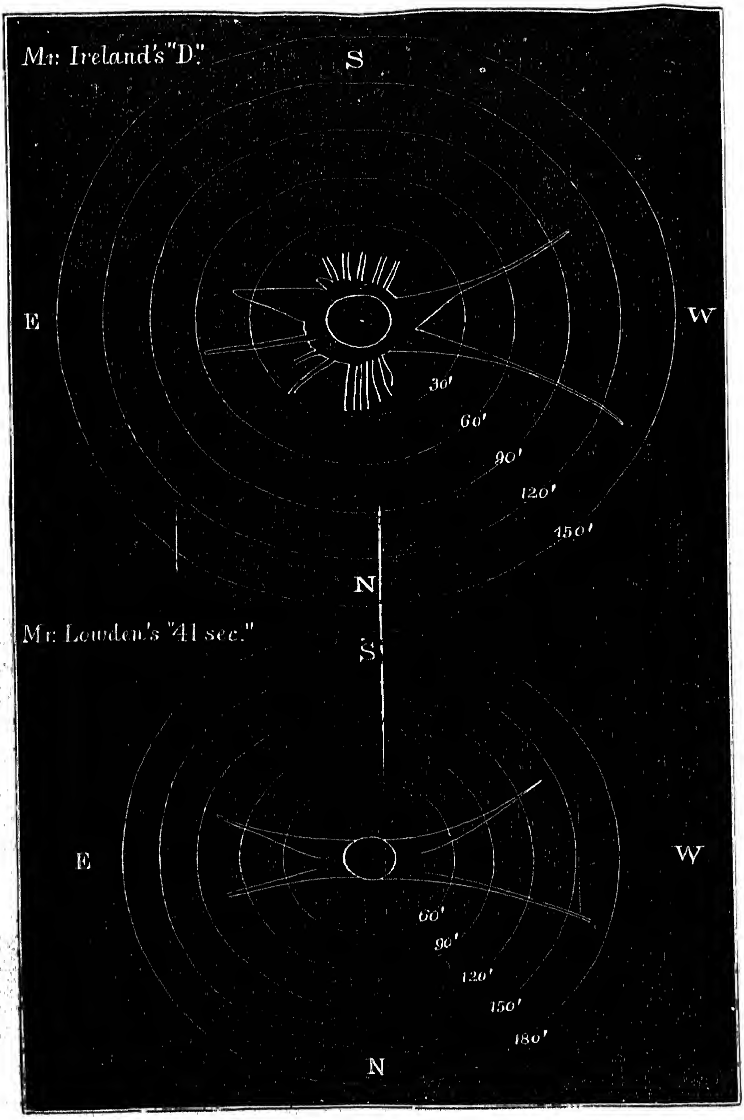

Figure 1; From Negatives by Messrs. Ireland and Lowden.

and the line (35–34) can be drawn as far as 65′ with no doubt whatever, and with considerable confidence as far as 89′, from these two authorities alone. Fortunately for the question, the Observatory also possesses a large number of photographs made by the members of the Amateur Photographic Association (see the

Reports in Part III.), and by other gentlemen in California. Quite a number of these yield important evidence on the question of the extension of the outer Corona, especially those of Messrs. LOWDEN, IRELAND, DORNIN, JOHNSON, TREAT, PASSAVANT, GRIMWOOD, LANGE, BURCKHALTER, and TABER. Two of them, however, made by Mr. LOWDEN and by Mr. IRELAND, respectively, are so remarkable and so conclusive, that we need only consider these two in order to obtain an entirely satisfactory portrayal of the outer coronal beams. It must be remembered that no previous photograph of the Corona has given definite outlines beyond 50′* from the Sun's centre so far as I know, and we are now concerned only with the description of the Corona beyond the circle of 65′.

As I have said, the photographs of Mr. BARNARD, together with the drawing of Miss TREAT, carry the outlines of the outer Corona out beyond the 80′ circle.

The photographs of Messrs. IRELAND and LOWDEN are naturally wanting in detail near the Sun, but beyond the 60′ circle they serve to carry the outlines of the four coronal wings† as far as 135′ and 165′, respectively.

The shortest way to present the evidence of these pictures is to copy their main outlines, which I have done in figure 1.

The scale is different for the two figures, but the circles concentric with the Moon's centre will serve as means of comparison.

The copies of the pictures of Messrs. IRELAND and LOWDEN have been made from positives (and are reversed N. and S. from the Index map of Mr. BARNARD's pictures, as all measurements with the compasses had to be made on the glass and not the film side). A very summary examination of the pictures will show that the wings *certainly* extend as follows:

	IRELAND.	LOWDEN.
The north edge of the N. W. wing	96′	83′
The south edge of the S. W. wing	94	79
The axis of the S. E. wing	69	69
The axis of the N. E. ray or wing	79	76

*Mr. WESLEY in the *Observatory* for May, 1889, p. 205, says that the photographs of 1883 show an extension of 60′ from the limb. I have never seen these photographs.

† I prefer the word "wing," or something equivalent, to the expression "group of synclinal structure" in a general description, for the reason that it is merely descriptive and does not commit one to any supposition with regard to the elements of which a "wing" is made up. By wings, I mean the masses 27 to 35; 26 to 16; 84 to 95; 68 to 76.

Mr. Lowden's second plate (21 sec.) gives these distances to which the wings are *obvious* as 89′, 69′, 66′, 85′.

If the pictures are held obliquely in a strong, soft light, or moved gently in front of such a light, these limits are very much extended, and I am satisfied that the drawings will be verified by any one who will give the requisite attention.

The appearance of the planet *Mercury* on Mr. Lowden's plates, shows that the camera (which was kept pointed by hand by means of a finding telescope), did not follow the sun *exactly*. In spite of this fact, the extension of the outer Corona is extremely great, as we have seen. If this camera had been driven accurately by clock-work, we should have had even more detail and extent than they now show, remarkable as this is.

It should be said that Mr. Ireland's "D" shows the detail of the polar rays and of the inner Corona much better than Mr. Lowden's (where these were lost by imperfect driving of the camera during the long exposures), and it accordingly seems that Mr. Ireland's experiments as to light, exposure, plates, etc., should be repeated at some future eclipse, as well as those of Mr. Lowden.

It thus appears that the new feature of the Corona, which just begins to show plainly in the photographs of Mr. Barnard, and in the drawing of Miss Treat, is very satisfactorily portrayed in the negatives taken by Messrs. Lowden and Ireland at different places and with differing instruments. The new feature referred to is the widening of the outer Corona as it is seen farther and farther from the Sun.

Many other negatives by members of the Pacific Coast Amateur Photographic Association lend independent corroboration to the conclusion already drawn. I may also cite a beautiful negative by Rev. Father Charroppin, which extends nearly as far, is full of detail, and entirely confirms the existence of the trumpet-shaped extension of the outer Corona. It is printed in Professor Pritchett's Eclipse Report.

It is worthy of note that the drawings of the outer Corona by Professors Newcomb and Langley, at the solar eclipse of 1878, which show the outer Corona extending several degrees on each side of the sun, present no evidence of the branching forms in the negatives just described.

These branching forms seem, at first sight, to suggest that the outer Corona is due largely to the presence of streams of meteorites drawn in toward the Sun. As the extensions are chiefly in

the direction of the ecliptic, we might draw the further conclusion that such meteoric streams must have formed a part of the solar system for long periods of time, and that they are thus a permanent feature of the system.

It is, however, impossible to understand why the phenomena of the outer Corona present different typical and characteristic forms at epochs of maximum and minimum sun spot frequency, if these phenomena are due to the mere presence of swarms of meteorites about the Sun. The internal collisions of such swarms (giving the line spectrum) would be entirely independent of changes within the Sun. The disposition of the constituent reflecting particles in space (giving the continuous spectrum) would also be quite independent of changes in solar *activity*. The action of the Sun's heat or light alone, no matter how variable, upon swarms of meteorites in his neighborhood, cannot be conceived to produce the profound *periodic* changes of typical and characteristic forms which are facts of observation in the Corona.

We seem, therefore, to be forced to the theory that periodic changes in the outer Corona, sympathetic with periodic changes in solar activity, must be due to some solar radiation other than light—possibly thermal or electrical.

There is no connection proved by this drawing between the particular prominences visible and the streamers, and a direct connection of this kind is possibly *a priori* unlikely. It must, however, be said that the four chief prominences visible are at, or very near, the bases of characteristic coronal forms as they appear in the drawing.

An examination of the drawing shows that there are a few constantly recurring types of coronal structure. The polar rays exhibit the most pronounced type, perhaps. At the North pole the bright rays (98, 100, 102, 103, the lower part of 105, 108, 110, 111, 113, 2, 4, 6, the lower part of 8, etc.) are essentially of one type. They extend nearly radially near the poles, with a slight tendency to be convex towards the Sun's axis prolonged to the N.; 105 is curved and convex to the axis, while 8 is strongly concave in all of Mr. Barnard's negatives.

Many of the bright polar rays are doubled, as 109, 111, 113, 2, etc. The doubling, in many cases, does not appear to be due to a perspective projection of one ray upon another, but, so far as mere looks are concerned, the duplicity appears to be structural. We must, of course, imagine the whole area of the Sun's surface, near

the poles, to be bristling with a network of these radial beams, whose analogy to the Auroral beams on the earth is most marked. At the south pole of the Sun the same type occurs in 68, 67, 64, 62, 58, 56, 54, 52, 50, 48, 46, 44, 42, 41, 40, 39, 38, 37 (which has contrary curvature) 36, 35, etc. These rays are polar in situation, and constitute one type as to structure, which we may call the polar type.

The centre of radiation of each set does not appear to be at the Sun's centre. The dark rifts between the bright rays are usually fairly straight in general direction. Their sides are not rectilinear, however, when attentively examined and their roots are singularly terminated (notably in the case of 1).

The bright polar rays projected near the south pole are in general straighter than those at the north (which was turned away from the earth on January 1).

I have said, in what precedes, that we must conceive the whole surface of the Sun, near the two poles, to be bristling with these auroral (?) streamers; and this is the usual view of the matter.

I see no reason, however, for supposing that such rays are confined to regions near the two poles. On the other hand, the rays 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35 on the west side of the sun, and 80, 82, 94, 95, 97, 98 on the east side, appear to me to be of the same general nature as the bright polar rays. They are nearly always curved (though 80 and 82 are marked exceptions) and in general they are concave toward the sun's equator. If we examine the lines of force at the poles of a bar-magnet, there is no discontinuity between the families of rays at the ends of the magnet and those at the sides; and in the case of the Sun also, the rays of so called "polar" type appear to extend all around the disc.

There is no latitude at which we can say that here the polar rays end and a new species—equatorial rays—begins. For example, 58 is a polar ray; so is 64; so, it seems to me, is 80 in all but situation. Again, what is to distinguish 6, 8, 10, 12, 14 (which are all of the polar type) from 23, 25, 26 except their curvature and their situation? The equatorial rays are all projected, it must be remembered, on a bright background which does not exist at the poles. If this background were removed we should, I think, at once see that the typical polar rays do in fact extend all round the disc, being least plentiful at the Solar Equator. I would, therefore, consider that the first characteristic type of

structure consists of rays ordinarily called "polar," which do not seem to be connected with any bright background, and of such others (as 80 and 82, for example) *as have no connection with the wing-like extensions.*

It is clear that there is a second type of rays which *are* connected with the wing-like forms. The best examples of these are 71, 73, 75; 84, 86, 88, 90; and, probably, 18, 19, 20, 21. These give the peculiar striations to the wings, and form "groups of synclinal structure." A very interesting recurrence of a type is shown in the cases of (23, 24, 25), (36, 37, 38), (86, 88, 90), and, perhaps, at (60, 61, 62). The symmetric arrangement of these groups is noteworthy. It is interesting also to observe that the two darkest narrow polar rifts are nearly opposite to each other. I have found no cases of curved rays which bend completely over as in Mr. Wesley's diagram of the eclipse of 1871. (*Monthly Notices*, R. A. S., vol. 47, p. 501.)

As is well known, the solar spots occur chiefly in two zones, extending from 5 to 40 degrees of solar latitude, north and south. A few spots occur near the solar equator, none beyond 45 degrees of latitude. Carrington's observations (1853–61) show the greatest number of spots to be in latitudes 20° N. and S. Spoerer's observations (1861–67) show the greatest numbers in latitudes 10° N. and S. The wings of the Corona of 1889 have their axes about as follows, if we suppose them to be in the plane perpendicular to the line of sight:

N.W. wing, axis in latitude 48 N.
S.W. wing, axis in latitude 14 S.
S.E. wing, axis in latitude 28 S.
N.E. wing, axis in latitude 20 N.

Actinic Brilliancy of the Corona and Surrounding Sky at Totality as Deduced from Mr. Barnard's Negatives.

Following the example of Mr. W. H. Pickering in his eclipse observations of 1886, all the plates taken by the Lick Observatory party were prepared so that they could be utilized for the determination of the intensity of the coronal light. I have chosen the best negative for complete reduction, namely, Mr. Barnard's negative C.

This was taken with a telescope of 1.75 inches (44.45 mm.) aperture and of 49 inches (1.24 metres) focus, the exposure being 4.5 seconds. The unit of actinic intensity is the intensity of actinic effect produced by a standard lamp (exactly similar to

that of the Harvard College Observatory, and procured for us through the kindness of Professor Pickering—see *Annals* H. C. O., Vol. XVIII, No. V, pages 98, 100), shining through an aperture 1 mm. in radius for 1 second of time on a sensitive plate 1 metre distant. To reduce measures of brightness on the negative to the unit of actinic intensity which is in use both at the Harvard College Observatory and at the Lick Observatory, we must divide these measures by 4.5 (to correct for exposure time), and by $\frac{(22.23)^2}{(1.24)^2}$ (to correct for aperture and focus). This lens transmits 85% of the light incident.

The unit of area is one minute square for the Lick Observatory, and $\frac{1}{40000000}$ of the sphere for the Harvard College Observatory.

Mr. Barnard plotted for me on a scale of 2 inches=16′.54 from his measures of the eclipse negatives those relating to the actinic intensity of this negative C. (See his report, following, for a description of the accurate method followed in determining the points.) Through the various points laid down by Mr. Barnard I traced the limiting curved lines of equal brightness. These were transferred to a sheet of pasteboard, and weighed by Mr. Keeler. His results are

One square inch weighs 0.561 grammes.
The sun weighs 6.698 grammes.
Area sun—k weighs 3.398 grammes.
Area a—k weighs 1.898 grammes.
Area b—a weighs 3.140 grammes.
Area c—d weighs 3.059 grammes.
Area d—c weighs 3.860 grammes.

K was the line along which the actinic intensity was equal to that standard square (on the same plate C) which had been exposed for 96 seconds; *a* was the same for 64 seconds; *b*, for 32 seconds; *c*, for 16 seconds; *d*, for 8 seconds; *e*, for 4 seconds.

The sky was uniform all over the plate, and equal to $\frac{d+e}{2}$ or 6 seconds. I have assumed that the Corona between lines *k* and *a* had the brightness *a*, and so in other cases. Plates A and B, taken with the Voightländer lens, show the illumination of the sky to have been entirely uniform out to 37° from the Sun's centre at totality. I shall assume it to have been uniform over one half of the visible hemisphere (10,313 square degrees).

Since the surface of the ground is not invisible at a total eclipse, it follows that a certain quantity of light must be reflected from the Earth back into the atmosphere, where it is dispersed by the floating dust particles. I have not taken the illumination of the

ground into account in these reductions. It was probably more than balanced by the fact that high mountains surrounded the observing station and cut off a considerable portion of the sky.

It is also assumed, on the authority of Captain ABNEY, F.R.S. (*Mon. Not.* R.A.S. March, 1889), that the time of exposure of each standard square is a measure of the actinic energy of the light which produced it.

From the weighings of the different areas of the Corona (taking no account of the absorption of the lens as yet) I find:

Area between k and the sun	=414.2, has	27.69 units of light.
Area between a and k	=231.4, has	10.31 units of light.
Area between b and a	=304.1, has	6.77 units of light.
Area between c and b	=373.0, has	4.16 units of light.
Area between d and c	=470.6, has	2.62 units of light.
Total actinic light of the corona		=51.55 units of light,

in which the unit of area is one square minute. For a check I have assumed the mean diameters of the curves k, a, b, c, d, etc., for this negative from Mr. BARNARD'S report (*q. v.*), and have calculated the total light of the Corona from his measures, assuming the areas to be circles. The result agrees practically with that just given.

The exposure of the standard square which matches the area k was 96 seconds. Hence the intrinsic actinic brilliancy of the brightest part of the Corona is (neglecting the absorption of the lens) 0.067 units. In the same way the apparent intrinsic brilliancy of the polar rays is about 0.045 units. The exposure of the square matching the sky was 6 seconds, thence the apparent intrinsic brilliancy of the sky was 0.0042 units. The area of one half of the hemisphere in square minutes is 37,125,000. The lens transmits 85 *per cent* of the light from the standard lamp. The numbers above given must then be multiplied by 1.18 to obtain the true intrinsic brilliancies, etc. This has been done in the following table.

In the first column of the table I have given the results obtained by Mr. PICKERING'S expedition of 1886.

In Mr. PICKERING'S *Report*, page 103 (lines 8–11 from the bottom of the page), 37 square minutes or one four-millionth of the sphere is taken as the unit of area in computing the total brightness of the Moon. In line 15 from the top of the same page ("within 90° of the Sun"), it is tacitly assumed that 74 square minutes is the unit area. On page 104 (line 9 from top), 37 square minutes is taken as the unit area. I have therefore used 37 as a

multiplier to Mr. PICKERING's figures in all cases except that of the total actinic light of the sky, when the multiplier 74 is used. The results for total actinic and total visual light of the sky in the report of 1886 are avowedly but approximations. In our future work, both Mr. PICKERING and myself will use the square minute as the unit area.

	PICKERING—1886.	HOLDEN—1889.
Intrinsic actinic brilliancy of the brightest parts of the Corona	0.031	0.079
Intrinsic actinic brilliancy of the polar rays (about)	----------	0.053
Intrinsic actinic brilliancy of the sky near Corona	0.0007	0.0050
Total actinic light of the Corona	37.	60.8
Total actinic light of the sky	52000.	185625.
Total actinic light of the sky and Corona	52037.	185686.
Ratio of total coronal to total sky light (actinic)	1 to 1400	1 to 3043
Ratio of intrinsic brilliancy of the brightest parts of the Corona to that of the sky (actinic)	44 to 1	16 to 1
(The above results in the second column are from Mr. BARNARD's Negative C only.)		
Intrinsic actinic brilliancy of the sky at 1° from the sun in daylight (average)	40.	----------
Intrinsic actinic brilliancy of the full Moon	1.66	----------
Total actinic light of the full Moon (SD=16′.75)	1461.5	----------
Intrinsic actinic brilliancy of sky within 5° of the full Moon	0.000064	----------
Magnitude of the faintest star shown on the eclipse photographs	----------	2.3

From this table it appears that the polar rays are about 11 times as bright as the sky; and that the brightest parts of the Corona are $1\frac{1}{2}$ times as bright as the polar rays. Hence these are usually masked when they are projected upon the bright wings.

The intrinsic brilliancy of sunlight *plus* Corona (40.08) is $\frac{1}{500}$ part more than the brilliancy of the ordinary daylight 1° from the Sun (40.0). Hence it would seem that the Corona (which has a continuous spectrum) can never be photographed in full daylight on our present plates.

MR. BURNHAM has been kind enough to make some experiments for me in photographing the Moon in full daylight. With his small camera (aperture=$\frac{3}{4}$ inches, focus=9 inches) he has exposed five Seed 26 plates as follows:

May 9, 3 P. M., stop = $\frac{f}{44}$, exposure $\frac{1}{64}$ second,

May 9, 3 P. M., stop = $\frac{f}{44}$, exposure $\frac{1}{100}$ second,

May 9, 3 P. M., stop = $\frac{f}{70}$, exposure $\frac{1}{64}$ second,

May 9, 3 P. M., stop = $\frac{f}{70}$, exposure $\frac{1}{100}$ second,

June 7, ?, stop = $\frac{f}{44}$, exposure $\frac{1}{8}$ second.

The Moon shows fairly well on the first four plates and is just visible on the last. Without making an accurate reduction of these plates, it is clear that the Moon was *many* times brighter than the Corona and that the sky near the Moon was *many* times fainter than that within a degree of the Sun; and these experiments seem to me to have an important bearing on the question of photographing the Corona in full sunshine.

From Mr. PICKERING's eclipse report of 1886 I cite the following data relating to the visual brilliancy for comparison; the first of these is, however, extremely uncertain:

Total visual brilliancy of Corona and sky within 90° of the Sun	60. units.
Light of a candle at 12 inches	201.6 units.
Total light of a bright moonlight night at full Moon	4. units.

Mr. LEUSCHNER's results (see his report in Part II) are:

	Candle.	Lamp Units.
Maximum possible total light of Corona and sky	= 0.0342	= 4.28
Most probable total light of Corona and sky	= 0.0111	= 1.39
Most probable total light of Corona	= 0.0086	= 1.08
Most probable total light of sky	= 0.0025	= 0.31
Most probable intrinsic brilliancy of sky	= 0.00078	= 0.098

The values in the first column are in terms of a candle shining through glass. The units in the second column are comparable with those of Mr. PICKERING's report. It seems that this photometric work should be repeated at a future eclipse.

An interesting measure of the brightness of the sky at totality can be derived from Mr. BARNARD's negatives taken with the CLARK lens (A exposed 1^s; B, 3^s; C, $4\frac{1}{2}^s$), and with the VOIGHTLÄNDER lens (A, 1^s; B, 3^s). Mr. BARNARD finds from examining these plates that the star *Sigma Sagittarii* (visual magnitude, 2.3, according to the *Uranometria Nova*, and 2.30, according to the Harvard Photometry; photographic magnitude, *about* 2.3, according to a letter from Professor PICKERING), is just visible on some of these. The planet *Vulcan* (if it exists) is probably fainter than 6 mag., and there is thus little hope of discovering any such object by photography. Mr. BARNARD's negatives give—

Clark Camera; aperture 1.1 in.=27.9 mm; focus 23 in.=0.58 m. transmits 67 per cent of light from the standard lamp.

A, exposed 1^s; star invisible; sky at star=standard square exposed 4 seconds,
B, exposed 3; star invisible; sky at star=standard square exposed 3 seconds,
C, exposed $4\frac{1}{2}$; star visible; sky at star=standard square exposed 3 seconds.

Voightländer Camera; aperture 1 in.=25.4 mm.; focus 8.85 in. =0.23 m. transmits 60 per cent of light from the standard lamp.

NOTE.—The definition of this lens, which was used with the full aperture, was poor except in the centre of the field.

A, exposed 1^s; star invisible; sky at star=standard square exposed 3 seconds.

The outlines of the mountains about 25° below the Sun are just barely visible in this picture. The sky is uniformly illuminated out to 37° from the Sun.

B, exposed 3^s; star invisible; sky at star=standard square exposed 6 seconds.

The outlines of the mountains are quite clear and strong; about equal to standard square exposed for 2 seconds. The sky is uniformly illuminated. The plates were Seed No. 26 in each case.

The Clark Camera plates give, then

A, exposed 1^s from 4th to 5th sec. of totality; star invisible; intrinsic brightness of sky near star 0.0103 units,

B, exposed 3^s from 30th to 33d sec. of totality; star barely visible; intrinsic brightness of sky near star 0.0026 units,

C, exposed $4\frac{1}{2}^s$ from 111 to 115.5 sec. of totality; star visible; intrinsic brightness of sky near star 0.0017 units.

The Voightländer Camera plates give

A, exposed 1^s from 7th to 8th seconds of totality; star invisible; intrinsic brightness of sky near star 0.0157 units,

B, exposed 3^s from 37th to 40th seconds of totality; star invisible; intrinsic brightness of sky near star 0.0038 units.

Probably the bad definition of the unstopped lens at a distance from the centre of the field makes these results somewhat doubtful.

The plates A, B, and C, of the 49-inch telescope give

A, exposed 1^s from 4th to 5th second of totality; intrinsic brightness of the sky 100′ from the Moon 0.0055 units,

B, exposed 3^s from 30th to 33d second of totality; intrinsic brightness of the sky 100′ from the Moon 0.0049 units,

C, exposed $4\frac{1}{2}^s$ from 111th to 115.5 second of totality; intrinsic brightness of the sky 100′ from the Moon 0.0049 units.

The foregoing results indicate that useful and accurate measures of the brightness of the sky can be made at future eclipses by amateur photographers who will take the pains to photograph the sky in the neighborhood of bright stars and planets, and to standardize their plates before developing them.

Actinic Brilliancy of the Sky After Totality.

One of Mr. Barnard's negatives (Voightländer C) gives very interesting evidence in this regard. It was just barely caught by the reappearing Sun (see his report following). The narrow line of sunlight is beautifully broken up into beads. The polar rays are effaced, but the whole external boundary of the Corona on both sides of the sun is as clearly shown in this plate as in the two taken during totality, and it appears to be of nearly the same extent. On the side where the Sun has reappeared the outlines of the coronal shapes are perfectly well kept, but the density has fallen off considerably (though much less than one would have expected). On the other side there is little change in the Corona. This plate was exposed 10^s or more during totality, and 3^s or less after Contact III. To show how great the illumination of the horizon is in this Plate C we have only to compare it with Plates A and B taken by the same lens during totality. In the Plate A the outline of a mountain about $1\frac{1}{2}$ miles distant is just barely perceptible with great attention. In B the outline is clear and a few tall trees can be seen in outline along the ridge. In C all the trees on the ridge can be counted and many details of the forest on the mountain side can be easily made out.

The distribution of light in the sky has completely changed in plate C from the uniform illumination during totality which is shown by plates A and B.

By measures with a very accurate wedge of dark glass, I find that the sky light falls off *uniformly* from the Sun out to $6\frac{1}{2}°$ all around. The range of the wedge was not sufficient to bring the rest of the plate under measurement, and it was accordingly measured by Mr. Keeler with the disc-photometer according to the following plan. A series of squares about $\frac{35}{100}$ of an inch on a side was marked out in ink on the film side of the plate at different distances from the Sun's centre.

The centre of square *a* was 8° from the Sun and below,
The centre of square *b* was 4° from the Sun and below,
The centre of square *c* was 4° from the Sun and above,
The centre of square *d* was 8° from the Sun and above,
The centre of square *e* was 12° from the Sun and above,
The centre of square *f* was $15\frac{1}{2}°$ from the Sun and above,
The centre of square *g* was $19\frac{1}{2}°$ from the Sun and above,
The centre of square *h* was 23° from the Sun and above,
The centre of square *i* was 27° from the Sun and above,
The centre of square *k* was 21° from the Sun and above

The Sun was 11° from the nearest point of the crest of the mountain. A square c was chosen and each of the squares *a*, *b*, *c*, etc., compared with c when possible. c was 26° from the Sun and had less altitude by about 10°.

The light transmitted by *a*=0.240 c=0.077 s.
The light transmitted by *b*=0.239 c=0.076 s.
The light transmitted by *c*=0.339 c=0.108 s.
The light transmitted by *d*=0.469 c=0.150 s.
The light transmitted by *e*=0.595 c=0.190 s.
The light transmitted by *k*=1.000 c=0.319 s.
The light transmitted by *i*=1.32 c=0.421 s.

s is the light transmitted by the standard square marked on the plate 11sec, and exposed to the standard lamp for eleven seconds. s corresponds to 11 units of light.

On these measures we may remark that the falling off in the light from *b* to *a* is quite marked to the eye, though it could not be detected if the measures of the relative brightness of *a* and *b* just given were exact. As it will be best to employ only the measures of those squares *above* the sun, the determinations of *a* and *b* have not been repeated. If we plat these measures, and remember that the determinations with the wedge show the light to fall off *uniformly* out to 6½°, we can form the following table:

The light transmitted at 1° from the Sun=0.078 s=0.858 units.
The light transmitted at 5° from the Sun=0.120 s=1.320 units.
The light transmitted at 10° from the Sun=0.170 s=1.870 units.
The light transmitted at 15° from the Sun=0.235 s=2.585 units.
The light transmitted at 20° from the Sun=0.304 s=3.344 units.
The light transmitted at 25° from the Sun=0.387 s=4.257 units.

BRIGHTNESS OF THE CORONA AT DIFFERENT DISTANCES FROM THE MOON'S LIMB.

The careful measures made by MR. BARNARD upon his negatives (see Plate III, etc.) give the average distances from the Moon's limb at which the Corona in each negative has a brightness equal to each of the standard squares, *k*, *a*, *b*, *c*, *d*. These were formed on the several plates by exposures to a standard lamp for 96, 64, 32, 16, 8 seconds of time, and their brightness may, for our present purpose, be assumed to be proportional to their times of exposure.

The mean results of MR. BARNARD's measures are:

Negative A. 1sec exposure. 49in Telescope. The Corona has the brightness—*a*, 3′.89; *b*, 4′.90; *c*, 6′.74; *d*, 8′.91; *e*, about 10′; *g*, 100′ from limb of Moon.

Negative B. 3^sec exposure. 49^in Telescope. The Corona has the brightness—*a*, 3′.94; *b*, 5′.24; *c*, 7′.06; *d*, 9′.79; *e*, about 10′; *e* is brighter than sky at 100′ from limb of Moon.

Negative C. 4.5^sec exposure. 49^in Telescope. The Corona has the brightness—*k*, 3′.69; *a*, 4′.89; *b*, 7′.81; *c*, 10′.60; *d*, 11′.81; $\frac{d+e}{2}$ about 100′ from limb of Moon.

Negative B. 3^s exposure. Clark camera. The Corona has the brightness—*a*, 6′.75; *b*, 7′.93 from limb of Moon.

Negative C. 4½^s exposure. Clark camera. The Corona has the brightness—*a*, 7′.59; *b*, 9′.65 from limb of Moon.

On all of Mr. Barnard's negatives the light of the sky is sensibly uniform from 100′ from the limb out to the edge of the plate. In the Voightländer camera the plate includes more than 37° from the Sun's centre.

If we plat these results on squared paper, with the exposure times of the standard squares as abscissas, and distances from the Moon's limb as ordinates, we shall find, within the limits of the data, that increasing the exposure times of the negative plates increases the distance from the Moon's limb, at which a given brightness is found. And also that an increase of exposure of the negative plate helps the fainter portions of the Corona relatively more than it does the brighter portions. No law connecting the brightness of the Corona at any point with the distance of that point from the limb is obvious.

It has been suggested by Professor Harkness (Report on Eclipse of 1878, page 392, § 2) that the brightness of the coronal light varies inversely as the square of the distance from the Moon's limb. If we form the products of the exposure times of the various standard squares *a*, *b*, *c*, *d*, and the squares of the distances in arc from the Moon's limb where the brightnesses *a*, *b*, *c*, *d* occur, we shall find that this law does not hold good for the negatives in question.

Conclusions.

A careful examination of the pictures of the Corona, and of the index-diagrams (Plate II and Fig. 1), derived from them, appears to show, when taken in connection with the evidence from other eclipses:

I. That the characteristic coronal forms seem to vary periodically as the Sun spots (and Auroras) vary in frequency, and that the Coronas of 1867, 1878 and 1889 are of the same strongly marked type; which corresponds, therefore, to an epoch of minimum solar activity.

II. That so-called "polar" rays exist at all latitudes on the Sun's surface, and are better seen at the poles of the Sun, simply

because they are there projected against the dark background of the sky, and not against the equatorial extensions of the outer Corona. There appears to be also a second kind of rays or beams that are connected with the wing-like extensions.

These latter are parts of the "groups of synclinal structure" of Mr. RANYARD.

III. The outer Corona of 1889 terminated in branching forms. These branching forms of the outer Corona *suggest* the presence of streams of meteorites near the Sun, which by their reflected light, and by their native brilliancy, due to the collisions of their individual members, *may* account for the phenomena of the outer Corona.

IV. The disposition of the extensions of the outer Corona along and very near the plane of the ecliptic might seem to show that if the streams of meteorites above referred to really exist, they have long been integral parts of the solar system.

NOTE.—The conclusions III. and IV. appear to be contradictory to that expressed in I. The electrical theory announced by Dr. HUGGINS in the Bakerian lecture for 1885, seems to reconcile the conclusions I., III., IV.

V. The photographs of the Corona which were taken just before Contact II. and just after Contact III., prove the Corona to be a Solar appendage, and are fatal to the theory that any large part of the coronal forms are produced by diffraction. (See the photographs of Mr. WOODS and a discussion of them in the reports of Mr. KEELER.)

VI. The spectroscopic observations of Mr. KEELER show conclusively that the length of a coronal line is not always an indication of the depth of the gaseous coronal atmosphere of the Sun at that point, and hence to indicate the important conclusion that the true atmosphere of the Sun may be comparatively shallow.

VII. Mr. KEELER draws the further conclusion in his report (*q. v.*) that the "polar" rays are due to beams of light from brighter areas of the Sun illuminating the suspended particles of the Sun's gaseous envelopes.

In order that this conclusion may stand, it is necessary to show that all these "polar" beams are composed of rectilinear rays.

It appears to me that the beams Nos. 62 and 64 of the Index-Diagram (among others) present serious difficulties of interpretation in this regard.

VIII. The conclusions respecting the photographic and photometric values of the Corona and surrounding sky at totality are

exhibited in the tables accompanying the reports of myself, Mr. BARNARD, Mr. LEUSCHNER, and Dr. PASSAVANT (*q. v.*) An important conclusion from these measures seems to be that it is impracticable to photograph the Corona in full sunshine with our present plates, and that a photographic search for *Vulcan* is hopeless.

The report of Professor SCHAEBERLE (Part I) details the observations made by Mr. BURNHAM, Mr. SCHAEBERLE, and myself at the Lick Observatory, and presents the results of Professor SCHAEBERLE's careful measures of the eclipse photographs.

The reports of the Lick Observatory field party under the charge of Mr. KEELER, are given in Part II. The results of spectroscopic and other observations by Mr. KEELER, photographic observations by Mr. BARNARD, contact observations by Mr. HILL, and photometric observations by Mr. LEUSCHNER, are there given in full. Particular attention is directed to the manner in which the silver-print of the Corona, which forms the frontispiece of the present volume, has been made. It represents the absolutely autographic record of the eclipse, and the whole work of producing it has been done by Mr. BARNARD himself.

The reports of Mr. BURCKHALTER, Chief, and of the members of the eclipse expedition of the Amateur Photographic Association, are given in Part III. They call for no further remarks here, except to point out that the well considered plan of the expedition insured the capital results which have been attained. An attempt was made to reproduce one of Mr. BURCKHALTER's best negatives by photo-lithography, but the result was not satisfactory, and the plate is therefore omitted.

Part IV contains a summary of the many reports and observations which have been obligingly communicated to the Observatory by amateur (and professional) astronomers. It is a source of regret that the limited funds available will not permit us to reproduce a number of the excellent drawings and photographs of this class. The general agreement of the drawings of the Corona of 1889 is remarkable when we recollect the singular discrepancies in the sketches of the very similar Corona of 1878. M. TROUVELOT's drawing of 1878 should be specially referred to as a faithful reproduction of the main features of both these eclipses, as to many of the details and also as to general effect. Its excellence is not fully appreciated at first sight, because the artist has chosen to give details which the eye can see only by using the telescope, superposed on the streamers which the telescope does

not show to good advantage. Photographs, however, show all the details, and prove the drawing to have been faithful.

Various circumstances have interfered with the carrying out of several researches which had been planned in connection with the reduction of our eclipse observations. The more important of these can be subsequently undertaken. It appears, however, that the results of our observations and experience will be of more use to Science if they are promptly published than if the present report is any longer delayed. It has, therefore, been decided to print these results in their present state, and to return to some of the researches referred to at a future time. So far as our work is here presented, it is entirely complete. The breaking of the chimney of our standard lamp and the necessity of waiting several months before it could be replaced by another, which had to be imported from Europe, has been the chief cause of the annoying delays.

In conclusion, I wish to add that every pains has been taken to insure that a copy of the present Report should reach each observer whose work has been communicated to the Lick Observatory. If there are, unfortunately, any omissions, I request that notice of them be sent to the Observatory.

EDWARD S. HOLDEN.

LICK OBSERVATORY, MOUNT HAMILTON, 1889, June 1.

ADDENDUM:—It gives me pleasure to add to the preceding brief review of the work of the Lick Observatory at the Eclipse of January 1, 1889, the information that the kindness of certain friends of the Observatory (headed by Hon. C. F. CROCKER) has made it possible to send an expedition to observe the Total Solar Eclipse of December 21, 1889, at Cayenne, South America. This expedition will be chiefly a photographic one, and an attempt will be made to learn more of the curious extension of the outer Corona first shown in the negatives of January, 1889.

PART I. REPORT ON OBSERVATIONS AT THE LICK OBSERVATORY.

By Professor J. M. Schaeberle.

Professor Edward S. Holden, *Director of the Lick Observatory:*

Dear Sir: It having been decided to make a series of exposures, with the photo-heliograph of this Observatory, during the eclipse, at your request I took charge of this instrument, which was first put in position by Professor Todd, in 1882.

To test the position of the focal plane Mr. Burnham, who had charge of the photographic work, made a series of exposures both inside and outside of the assumed position of the focus. The quality of the images was, however, far from satisfactory. A distortion of some kind being suspected by yourself, both the objective and the plane glass reflectors were taken from their respective cells, and then again carefully replaced. A second series of exposures gave the data for fixing the plate-holder in its final position. After the objective and reticle plate had been carefully collimated, the distance between the inner glass surfaces of the objective and plate was determined by measuring (with a jaw-micrometer, specially made for this purpose) the distance from a plumb-line, hung from each end of the 40-foot standard rod to the nearest glass surface. These measures are:

Date.	Jaw-Micrometer Readings.		Temperature.	Sum of Readings.
	North End.	South End.		
1888, December 27	6.137	6.610	37°	12.747
1889, January 2	6.945	5.785	47	12.730

Thickness of plumbline=0.009 inch.

A surveyor's level, placed between the 4-inch transit and the photo-heliograph objective, was used to determine the position of a horizontal point on the glass plate. On December 27th it was found that the upper ledge of the letter *B*, in the word *OBS.* engraved on the glass plate, was in a horizontal line passing through the optical center of the photo-objective. A second series of

measures made on January 2, 1889, gave 0″.93 as the inclination of this same line, the south end being depressed.

To determine the azimuth of an optical axis passing through the plumb-line in the focus of the photo-objective, two series of observations were made with the 4-inch transit, which is mounted in the meridian of the photo-heliograph. The image of the plumbline, as seen in the 4-inch transit, was on the west side of the middle wire.

Date.	Azimuth Constant of 4-inch Transit.	Distance of Plumb-line from Collimation Axis.	Azimuth of Plumb-line.
1888, December 27	$-0^s.140$	$+1^s.802$	$+1^s.662$
1889, January 2	-0.184	$+1.902$	$+1.718$

On the day of the eclipse, soon after the first contact had been observed, the clouds became so dense that the Sun was wholly obscured. Later on, however, the weather became more favorable, so that photographs could be taken. Professor Holden was stationed at the objective-end of the telescope, regulating the motion of the heliostat mirror, so that the Sun's image remained properly centered. Mr. Burnham manipulated the dry plates, and made the exposures by moving the slide (having a vertical slit one quarter of an inch in width) across the field as rapidly as possible, the exact time of exposure being automatically rcorded on the chronograph. I also recorded the times taken directly from a chronometer (No. 1617) placed in the dark room. These times are given in the following table:

List of Photo-heliograph Negatives, January 1, 1889.

Pencil Number	Engraved Number	Weather.	I. Chron. 1667. J. M. S.			II. Chronograph.			L. O. Mean Time. By I.			L. O. Mean Time. By II.		
			h	*m*	*s*	*h*	*m*	*s*	*h*	*m*	*s*	*h*	*m*	*s*
1	214	Clear	1	24	57.10	21	14	0.70	1	23	59.74	1	23	59.82
2	203	Clear		33	6.2		22	11.10		32	8.84		32	8.78
3	115	Clear		46	13.1		35	20.80		45	15.76		45	16.31
4	198	Cloudy		52	28.6		41	36.88		51	31.27		51	31.35
5	197	Cloudy		54	20.7		43	29.25		53	23.37		53	23.41
6	196	Cloudy		56	56.6±		46	5.50		55	59.28		55	59.26
7	200	Clear	2	5	45.3		54	55.75		4	47.99	2	4	48.02
8	199	Clear		10	38.3		59	49.45		9	41.00		9	40.92
9	213	Clear		20	45.3		9	58.15		19	48.01		19	47.94
10	------	Clear		29	12.6		18	27.02		28	15.32		28	15.41
11	210	Clear		35	28 5		24	43.75		34	31.22		34	31.10
12	211	Clear		41	11.7		30	27.80		40	14.43		40	14.21

Temperature=46° Fah. Barometer=$25^{in}.906$.

The dry plates were specially prepared for this work by Dr. S. C. Passavant of San Francisco.

Constants of the Photo-heliograph.

A memorandum of certain constants of the photo-heliograph has been kindly communicated by Professor William Harkness, U. S. N., from the records of the U. S. Transit of Venus Commission, and from his own investigations. I have added the values of (2,) (4), and (6), which hold good for January 1, 1889.

"Let

(1)=Length of the measuring rod at t°F,

(2)=Sum of jaw-micrometer readings,

(3)=Correction to ditto,

(4)=Diameter of plumbline wire,

(5)=Interval between second principal point and back surface of objective,

(6)=Correction to ditto on account of curvature of heliostat-mirror,

(7)=Optical thickness of reticle plate,

(8)=Interval between back surface of reticle plate and sensitive film;

Then, Equivalent focal distance of the photoheliograph=(1)+(2)+(3)+(4)+(5)+(6)+(7)+(8).

For the Lick photo-heliograph:

(1)=466.127 inches+0.00308 (t—62);

(2)=12.732 inches.

(3)=—0.0114 inches—0.0016 (R+R′—10.00);

(Where R & R′ are the two readings)

(4)=0.009 inches;

(5)=0.401 inches;

(6)=$\left(\frac{2\Phi}{R}\right) T \sec. \frac{1}{2}\theta$;

(Where Φ=focal distance of objective, R=radius of curvature of heliostat-mirror, which, when exposed to the rays of the Sun, was found to be 26.67 miles. T=Interval between objective and mirror. θ=Angle subtended at the mirror, between the sun and the reticle plate.)

For the observations of January 1 we may take

Φ=479.35 inches,

R=26.67 miles,

T=27 inches,

t=46°

Whence

(6)$=\frac{958.7}{1689808}\times 27\times$ sec. 26° 15′=0.016 inches,

(7)=0.179 inches for blue light of wave length 0.425 μ,

(8)=0.190 inches.

The equivalent focal length of the telescope was, therefore, 479.399 inches.

The value of (6) is dependent upon the time of exposure, since θ is a function of the Sun's hour angle; it can, however, be regarded as constant during the time the photographs were being taken. The values of (6) corresponding to hour angles of the sun equal to 1^h and 3^h are respectively $0^{in}.0159$ and $0^{in}.0166$.

Measurements of the Photographs.

With the exception of the plates numbered 4, 5, and 6, all photo-heliograph negatives taken on the day of the eclipse were measured on the excellent measuring engine belonging to this Observatory. Nos. 4, 5, and 6 were spoiled by clouds.

The surface to be measured is placed upon a table which can be adjusted in all three coördinates. This table is fastened to a vertical shaft which can be revolved in its bearings and the angle turned through read off, with the aid of two verniers reading to 5″, on a graduated circle near the lower end of the shaft.

On the same framework that supports the shaft, and above the table, is a double slide (giving rectilinear motions in two directions at right angles to each other), which carries the wire micrometer-microscope for examining the plate.

Two other microscopes, one for each slide, containing fixed lines in the focus, which can only be brought into exact coincidence with a line on the measuring scale by moving the whole slide, are used in measurements of distances exceeding one or two revolutions of the micrometer screw. The slides are always moved an exact whole number of divisions, the fractional parts of the distance measured being obtained with the micrometer screw.

In the eclipse photographs the image of the Sun was first centered by rotating the plate under the microscope. A small piece of paper having two very fine intersecting lines marked on the surface with a sharp knife, was shifted about under the microscope until the intersection of the lines coincided with the axis of rotation. In this position it was cemented directly to the film, so that the coördinates of the sun's center referred to the intersection

of the middle horizontal and vertical lines of the plate could be measured directly.

In measuring the distances between the cusps one of the two readings of the upper scale microscope, "Scale A," was always 280, in order that any division errors of the particular lines used in these measures can hereafter be allowed for. (For the same reason, in one of the two circle readings the verniers always stood at the 0° and 180° lines.) As the effect of such errors in the measured coördinates x, y, of the Sun's center will be insensible, so far as the resulting place of the moon is concerned, no attempt was made to use any particular lines of the scale in measuring x and y. To avoid any correction for "runs" the micrometer-microscope was so set that one turn of the screw was *apparently* just equal to one division of the measuring scale. The magnifying power of the micrometer-microscope was about 15. To determine the position-angle of the line joining the cusps the plate was first rotated until the image of the plumbline remained bisected by a point in the field of view of the micrometer-microscope, while the latter was being moved across the image of the Sun's disc. [The probable error of a single setting is *about* 10″, depending of course on the length of the line visible on the plate. This probable error could be considerably diminished were it not for the curious fact that the image of the plumbline is in places slightly curved. It is, however, certain that the plumbline itself was in fact straight. That this apparent curvature is not due to a curvature of the track for the slide, was demonstrated by mounting a telescope on the slide and observing the images of the wires of a collimating telescope. The phenomenon may possibly be due to a curvature of the glass surface covered by the film.] The verniers were then set to read, approximately, 0° and 180°, and the exact circle reading recorded. The plate was then rotated until both cusps passed through a given point in the field of view of the sliding microscope.

Under the microscopes the cusps are all rather ill-defined, some more so than others, so that I have thought it well to give the probable error of each tabulated angle and distance. These probable errors could, of course, have been made smaller by fixing on some particular points in the ill-defined boundaries, but I deemed it to be more trustworthy to make each observation wholly independent of all previous ones.

From the measurements it appeared that the plumbline was disturbed several times during the eclipse. To make sure that no

accidental errors of appreciable magnitude resulted from this cause, the following observations, giving the position of the plumbline referred to the middle vertical line of the plate, were made:

No. of Plate.	Distance.	Inclination.
	d	
1	1.71	1′ 50″
2	1.69	1 27
3	1.58	2 7
7	1.53	1 22
8	1.58	Sensibly parallel.
9	1.48	Sensibly parallel.
10	1.45	1 7
11	1.47	1 12
12	1.45	1 33

The practical constancy of the inclination shows that the plumbline was apparently in its "normal" state at the times of the several exposures.

On plates 3, 7, 8 and 9 only one horn of the crescent image of the Sun was crossed by these two lines, and on plates 3, 8 and 9 these lines could only be traced a short distance beyond the boundaries of the crescent. On December 27 and January 2, the angular distances between the plumbline and the middle (vertical) line of the plate, as measured with the transit instrument, were $-0^s.832$ and $-0^s.900$, respectively. The resulting azimuths of the middle line for the two dates are therefore $+0^s.830$ and $+0^s.818$. In the reductions I have used the mean value $+0^s.824 = 12''.36$. The middle *horizontal* line of the plate is $5^d.60$ of the scale of the measuring engine *below* the adopted zero or horizontal point. The value of one division (d) of the scale is $0^{in}.02$. Using the computed focal length already found the angular value of d comes out $d = 8''.602$ hence $5^d.60 = 48''.17$. As a matter of some curiosity, I measured, roughly, the diameters of the images on plates 7, 8, 9, 10, 11 and 12; the above value d gives for the semi-diameter in each case 976″.3, 976″.2, 976″.5, 976″.3, 975″.8 and 978″.2; mean 976″.6, refraction being unallowed for. The American Ephemeris gives 976″.2. In the following table, the angles are measured from the nadir-point toward the *west*. The measured coördinates x, y of the Sun's centre are considered as positive in the upper eastern quadrant, and are referred to a system of rectangular axes, having the origin at the intersection of the central lines of the plate, the axis of Y being parallel to the plumbline. The spherical coördinates a and b give the azimuth and altitude of the line passing

through the optical centre of the photo-helio-objective and the centre of the sun's image at the instant of exposure.

Resulting Measures.

No. of Plate.	Distance Between Cusps.	Probable Error (Five Measures).	Position Angle of Cusps.	Probable Error (Four Measures).	Coord's of Sun's Center. x.	Coord's of Sun's Center. y.	Sph. Coord's of Sun's Centre. Azimuth. a.	Sph. Coord's of Sun's Centre. Altitude. b.
	d.				d.	d.		
1	221.506	±0.005	352° 17′ 21″	±39″	+35.16	+22.52	+315″	+146″
2	226.468	5	356 26 33	26	+63.57	+ 7.55	+559	+ 17
3	217.636	7	83 33 30	50	+25.97	—33.20	+236	—334
7	222.306	4	147 7 15	42	+15.28	+21.02	+144	+133
8	218.239	4	147 53 42	13	— 8.25	— 2.66	+ 59	— 71
9	206.842	3	147 57 30	16	+10.91	— 5.44	+106	— 95
10	193.206	8	147 24 59	18	— 6.50	+12.49	+ 44	+ 59
11	181 077	10	146 47 15	11	+13.48	+19.66	+128	+121
12	166.176	13	146 7 28	23	+10.99	+26.86	+107	+183

With the exception of the undetermined corrections due to error of graduation, shrinkage of the .film, and the phenomena of irradiation, all the data necessary to be obtained from the photographs are given above.

Observation of the Contacts.

For observing the contacts Professor Holden used the 6-in. finder of the 36-in. equatorial; at the last contact, owing to the great zenith-distance of the sun, this particular finder was beyond the reach of the observer, so that no attempt was made to obtain the time of the fourth contact with it.

Mr. Burnham observed both contacts with the 12-in. equatorial, using the chronograph for recording the time; but owing to a cross in the wires, through no fault of the observer, the time of the last contact was lost on the sheet. For my own observations the 4-in. finder of the 36-in. telescope was used.

Professor Stringham, of the University of California (for the time being a guest of Professor Holden), gave the chronometer times to both observers in the great dome by counting whole second beats of this time-piece.

Mt. Hamilton Mean Times of the 1st and 4th Contacts.

Observer.	1st Contact.	4th Contact.	Remarks.
E. S. H.	$0^h\ 18^m\ 22^s.0$	----------------	----------------
S. W. B.	0 18 30.3	----------------	Indentation plain.
J. M. S.	0 18 25.3	$3^h\ 3^m\ 48^s.2$	1st contact, indentation plain; 4th contact, may be as much as two seconds late.

All possible chances of seeing that portion of the Moon's outline which was projected against the Corona, were, of course, destroyed by the haziness of the sky during the whole time of transit.

For the benefit of the various observing parties throughout the State the following corrections to the Pacific Standard Time Signals, sent out from this Observatory, are also included in this report:

Date.	Corrections to reduce to Pacific Standard Time.
1888, Dec. 30.00	$+0^s.98$
1888, Dec. 31.00	+0.35
1889, Jan. 1.00	−0.18
1889, Jan. 2.00	+0.01

Respectfully submitted.

J. M. Schaeberle,
Astronomer of the Lick Observatory.

Mt. Hamilton, Jan. 18, 1889.

PART II. OBSERVATIONS AT THE FIELD STATION OF THE LICK OBSERVATORY, AT BARTLETT SPRINGS.

By James E. Keeler.

Dear Sir: I have the honor to submit herewith the reports of the members of the Lick Observatory field party who were stationed at Bartlett Springs, Lake County, California, for observation of the total solar eclipse of January 1, 1889.

This station was selected by yourself after a study of the meteorological records kept at various points in the line of totality. One of the desirable conditions was a considerable altitude, and for the accessible places of this kind, the chances of clear weather were slightly in favor of Bartlett Springs. Fortunately clear skies prevailed at the time of the eclipse throughout nearly the entire State.

Preliminary Visit to the Eclipse Station.

In October of the preceding year, while spending a vacation in Lake County, I paid a visit to Bartlett Springs and selected an open piece of ground near the hotel as a suitable point for the observations. A better place was, however, found before the eclipse. From a map of the State the approximate position of Bartlett Springs is latitude 39° 17′; longitude 8^{h} 11^{m}.

The altitude of the station was roughly determined by the following readings of a small pocket aneroid barometer belonging to Captain R. S. Floyd, who furnished the corrections for reducing the reading of the aneroid to that of a mercury barometer at 32° Fahr.

Place.	Time.	Aneroid.	Temp.	Barom. at 32°.
		in.	°	*in.*
Lakeport	Oct. 25, 7 A. M.	28.02	56	28.61
Bartlett Springs	Oct. 25, 3 P. M.	27.11	62	27.73
Bartlett Springs	Oct. 26, 10 A. M.	27.12	71	27.82
Steamer on Clear Lake	Oct. 26, 5 P. M.	27.74	79	28.53

These observations give a difference of elevation of 730 feet. The height of Clear Lake above the sea level is 1,310 feet. Hence the height of Bartlett Springs is 2,040 feet.

Projected Work of the Party.

The authorized members of the Observatory party were
James E. Keeler, Astronomer.
E. E. Barnard, Astronomer.
Chas. B. Hill, Assistant Astronomer.
Armin O. Leuschner, Graduate Student in Astronomy.

My own work was to be a repetition of the spectroscopic observations made by Professor C. S. Hastings, at Caroline Island, in 1883, and the observation of such additional phenomena of interest as should present themselves. For this purpose the rather short duration of totality was of less consequence than for the photographic and photometric work

Mr. Barnard had entire charge of the photographic work of the party. His object was to secure the best picture of the Corona that was possible with the apparatus at his command, and to make other exposures for special purposes, which will be set forth in his report.

Mr. Hill was to look for certain possible changes in the Corona during totality, to assist me in my work with the spectroscope, and to observe the times of contact. This last class of observations had not been considered in arranging the work of the expedition, but as it was found that the contacts could be observed without interfering with the original programme, the times of 1st, 2d, 3d, and 4th contacts were noted by Mr. Hill, those of the 1st and 4th also by Mr. Barnard, and the observations will become available if at any future time the position of the station shall be determined.

To Mr. Leuschner was assigned the photometric comparison of the Corona with a standard candle by means of a wheel photometer just received from Mr. J. A. Brashear. With the aid of observations to be made after the eclipse at the Lick Observatory, it was intended to eliminate the candle used in the comparisons, and express the coronal light in terms of that of the full Moon. Mr. Leuschner also took charge of the chronometer.

Preparations for the Expedition.

For several weeks prior to the eclipse I was occupied in superintending the construction of different parts of the apparatus by the Observatory mechanic, in packing the instruments when ready for use, and in fitting up the spectroscope and adapting it

to the 6½-inch equatorial. The clock-work of the 12-inch telescope was arranged to drive a polar axis carrying the photographic cameras, and the performance of this piece of apparatus was entirely satisfactory, although as fewer cameras were actually used than originally intended, the construction of the polar axis might have been lighter and simpler.

TRIP TO BARTLETT SPRINGS AND OPERATIONS PRIOR TO THE ECLIPSE.

The packing was completed on December 15, and on the next day Mr. BARNARD, Mr. LEUSCHNER, and I left the Observatory with the boxes, which we sent by freight to Bartlett Springs. After spending two days in San Francisco making necessary preparations, we left for Sites, in Colusa County, on the morning of December 19, and arrived there late in the evening. Sites is the western terminus of a small narrow-gauge road which crosses the northern branch of the Southern Pacific at Colusa Junction, and from this point communication is had with Bartlett Springs, about thirty-five miles to the westward among the mountains, by means of stages. From a hill near the town Mount Shasta could be seen as a dim white spot upon the northern horizon.

The next stage left Sites on Friday morning, but as our boxes had not yet come I stayed behind in order to look after them, while Mr. BARNARD and Mr. LEUSCHNER went on to the station to prepare for the erection of the instruments. The weather was extremely unpromising. Rain fell nearly all the time, and the little town of Sites was surrounded by a vast sea of mud.

On the evening of the same day I learned that the boxes had reached Williams, the next station below Colusa Junction, and would be sent at once from that place to Bartlett's in wagons.

As no stage would leave Sites until the next Monday, I went over to Colusa on Saturday to see if I could get the telegraph line to Bartlett's Springs, a branch of the Pacific Postal Telegraph Company's system, put into such shape that we could transmit messages and receive the time signals from the Lick Observatory. This the manager in Colusa kindly consented to do, and sent a line man out at once to repair the wire.

At seven o'clock on the morning of December 24th I left on the stage for Bartlett Springs with Mr. GEO. W. YOUNT, the manager of the hotel at that place, and a number of other passengers. The long rains which had been falling on the *adobe* soil, and the stage travel, made the roads muddy beyond anything that I remember

having seen before. We had to walk up the steep hills, and at short intervals it was necessary to stop and dig the mud off the wheels, in order that the four horses could drag the empty stage. At that time it did not seem possible that our boxes could reach the summit, but as the whole country was well within the limits of totality we were fairly sure of obtaining observations of some kind, even if it should be necessary to set up the instruments on the scene of a possible accident. It was ten o'clock at night when we reached Bartlett Springs, having been fifteen hours on the road.

The next morning I found that Mr. BARNARD had discovered a much better site for the erection of the instruments than the one I had selected in October, and in a clear interval had established a meridian line by observation of *Polaris*, and put up piers from drawings which had been made before leaving the Observatory. The boxes had just arrived, and we proceeded at once to unpack them and place our apparatus in position.

Bartlett Springs is situated on the northeast side of a narrow valley, which runs in a general southeasterly and northwesterly direction between ranges of hills rising occasionally to a height of some two thousand feet above the valley. Numerous mineral springs are found among the hills, all heavily charged with carbonic acid gas, and near one of the largest of these Messrs. McMAHAN have built a hotel and many cottages, which are occupied by those who resort to the springs in order to benefit by the medicinal properties of the water. The place selected for our observations was an abandoned croquet ground of the hotel, elliptical in shape and about sixty feet long, situated on the top of a low hill overlooking the valley. As nearly as we could estimate before setting up our instruments, the Sun at the time of fourth contact would be just clear of the summit of the range on the other side. A small cottage close to the ground was placed at our disposal by Mr. YOUNT for the storage of instruments and other purposes. The hotel was not more than two hundred yards distant toward the west, and the telegraph office was still nearer.

The 6-inch telescope was erected in the middle of the inclosure (for the croquet ground was surrounded by a low guard of boards), the polar axis and clock work for the cameras were placed on the left, and the right, or west end, was assigned to the photometric apparatus in charge of MR. LEUSCHNER. Our operations were much hindered by the rain, which continued to fall at frequent intervals, and the prospect of seeing anything of the

eclipse was most unpromising. On account of the smallness of the appropriation it had been decided not to provide a field observatory or hut, and instead of this suitable waterproof covers for the instruments had been ordered of a San Francisco firm. These, however, were not delivered, but with the aid of a number of small tarpaulins that we had brought with us, and some canvas furnished by Mr. YOUNT, we were able to do very well without them.

Mr. HILL arrived on the evening of December 28th. The next two days were fair, although with occasional showers, and we were enabled to get everything into good working order. Mr. BARNARD adjusted his cameras and practiced methods of exposure; Mr. LEUSCHNER experimented with the photometer and made comparisons of artificial lights; and Mr. HILL and I studied the performance of the telescope and spectroscope. Mr. HILL and Mr. LEUSCHNER compared the chronometer daily at noon with the beats of the Lick Observatory clock, whenever the telegraph line was in sufficiently good working order to enable signals to reach us.

Our strength was increased at about this time by several volunteer observers. Mrs. C. B. HILL practiced noting time by the chronometer at a given signal. Mr. F. B. STAPLES, of Oregon, a guest at the hotel, turned the photometer wheel and otherwise assisted Mr. LEUSCHNER. Mr. H. A. MCCRANEY, editor of the "Lakeport Avalanche," volunteered to time the duration of totality with one of two stop-watches which had been lent to the expedition by Mr. F. H. MCCONNELL, of San Francisco. A number of others prepared to make sketches of the Corona.

The morning of December 31st was clear, and we spent most of the time in rehearsing the programme for the eclipse. In the afternoon clouds came up again, and by night the sky was heavily overcast, promising nothing but rain for the next day. Much to our delight, notwithstanding our gloomy expectations, the Sun rose in a beautifully clear sky, and the weather was the finest we had seen since leaving the Observatory.

GENERAL ACCOUNT OF THE OBSERVATIONS.

The morning was spent by the party in rehearsing the programme again, and in making final preparations. A bank of clouds came slowly up from the west, but so slowly that we were in hopes the eclipse would occur before they reached the Sun. At

eleven o'clock the Sun was covered with thin, fleecy clouds, but in the west the sky was lighter, and we were confident that we should obtain at least a fair view of the eclipse.

Mr. HILL and Mr. LEUSCHNER got time signals from Mt. Hamilton at noon, and immediately afterward we took our stations in the inclosure. The computed chronometer time of first contact was $0^h\ 30^m\ 52^s$, and at $0^h\ 28^m$ I began to beat the seconds of the chronometer on a brass telescope cap, calling aloud every tenth second, and at the sixtieth the corresponding minute. Mr. BARNARD noted the time of first contact with his 2½-inch telescope, and Mr. HILL with the finder of the 6-inch equatorial, by means of these beats. I continued the count until about $0^h\ 31^m\ 30^s$, when Mr. BARNARD and Mr. HILL coming up with their results announced that the first contact had occurred. The sky was at this time quite clear, except in the west, where fleecy clouds still reached well up toward the Sun. They appeared, however, to be gradually dissipating.

When the sun was about half obscured Mr. HILL called my attention to the fact that he could trace the limb of the Moon for a short distance off the Sun's disc, with the finder of the telescope. I was also able to see this, holding a wedge of neutral tint glass in front of the eyepiece, and found the appearance more noticable on the northern than on the southern limb. The distance through which the Moon's edge could be traced was perhaps 2′.

As the time of second contact drew near, the usual darkening of the landscape and other phenomena attending a total solar eclipse were noticed. Fifteen minutes before totality lanterns were lit and placed in position, and I removed the cardboard stop with small aperture, which up to that time had covered the object glass of the telescope. The stations of the different members of the party were as follows:

J. E. KEELER, at the spectroscope of the 6½-in. equatorial.

E. E. BARNARD, at the photographic apparatus.

C. B. HILL, at the finder of the 6½-in. equatorial.

A. O. LEUSCHNER, at the photometer.

Mrs. C. B. HILL, at the chronometer.

H. A. MCCRANEY, with stop watch near chronometer.

F. B. STAPLES, turning photometer wheel.

GEO. W. YOUNT, at easel with oil colors for painting.

Mr. FRED. KLAYS, Mr. P. MCGEE and others were prepared with paper and pencil for sketching.

Mr. Hill called ten minutes and five minutes before totality, and then as it rapidly grew dark, gave warning of the approach of second contact. I glanced up at the sky and saw it quite clear in general, although slightly hazy in the direction of the Sun, around which a few small feathery clouds were floating at a distance of several degrees. Looking around at the landscape, I saw none of the so-called diffraction bands which were so striking a feature of the total eclipse of July 29, 1878, in Colorado, and on making inquiries afterward, I found that no appearance of the kind had been observed by any of the bystanders. I then turned to the spectroscope, and perhaps ten or fifteen seconds later, Mr. Hill called "time."

The observations which I made with the spectroscope will be described further on. The principal phenomena which were to be noted occurred at the beginning and end of totality, and when the eclipse was about half over I looked up at the sky for nearly a quarter of a minute.

The Corona was beautifully bright and distinct; according to my recollection, brighter than that of 1878, which I observed at Central City, Colorado. It was apparently of the same type, but much more marked, with a broad "fish-tail" mass of light extending some two diameters of the Moon on each side, nearly in the direction of the ecliptic. Its general outline was so definite that I remember thinking that in the drawings of this eclipse such discrepancies as occur among those made in 1878 could hardly be possible. *Mercury* shone brilliantly a short distance to the southeast. Looking around me I could see the other members of the party at work, and could easily see the few notes which I had written upon a card. I then once more turned my attention to the spectroscope.

At 1^m 40^s after second contact Mr. McCraney, according to his instructions, gave warning of the approaching end of totality. When the sunlight flashed out again I was still engaged at the spectroscope and did not note any of the phenomena of reappearance, but I learned that no diffraction bands had been seen by those who were unoccupied.

The observations during totality had been made closely in accordance with the plan we had practiced, except that, as was to be expected, not quite so many exposures of the cameras were made, not quite so many photometric comparisons obtained, and not quite the same amount of work accomplished. All the

results were apparently satisfactory. The chilliness of the air during the total phase was very marked, but no meteorological observations were made.

An oil sketch of the Corona was made during totality by Mr. YOUNT, and another, with corrections, immediately afterward. Sketches were made during totality by Mrs. C. B. HILL, Mr. FRED. KLAYS, and Mr. P. MCGEE. Mr. STAPLES, who had a good opportunity to see the Corona while turning the photometer wheel, made a sketch after totality. All of these are in excellent agreement.

Half an hour after the total phase was over, clouds began to cover the western sky. I removed the spectroscope and gave up the telescope to Mr. HILL, who observed the time of fourth contact with it through the fast-thickening clouds. Mr. BARNARD observed with the 2½-inch telescope, while I beat the seconds of the chronometer as at the beginning of the eclipse. Immediately afterward we began the work of dismounting the instruments, and by the evening of the next day had them packed ready for reshipment to the Observatory. On account of the bad condition of the roads they were stored at the hotel, and did not reach the Observatory until two months later.

Our good fortune in regard to weather is apparent when I state that the first of January was the only day during the time we spent at the station on which the eclipse could have been successfully observed.

Our party received much assistance from the inhabitants of Bartlett Springs and from visitors. Some of the services have already been mentioned. To Mr. GEORGE W. YOUNT, in particular, we were indebted for every act of courtesy which could add to our personal comfort or contribute to the success of our observations. To all we desire to tender our grateful acknowledgments.

Leaving a further account of all except the spectroscopic observations to the individual reports of the other members of our party, I will now describe in more detail the apparatus used by myself, and the results which were obtained with it.

DESCRIPTION OF THE SPECTROSCOPIC APPARATUS.

The telescope which I used is the 6½-inch equatorial, briefly described in Vol. I, Publications of the Lick Observatory, from which the accompanying illustration is taken. The object glass, 6.4 inches in clear aperture and 76 inches in focal length, was

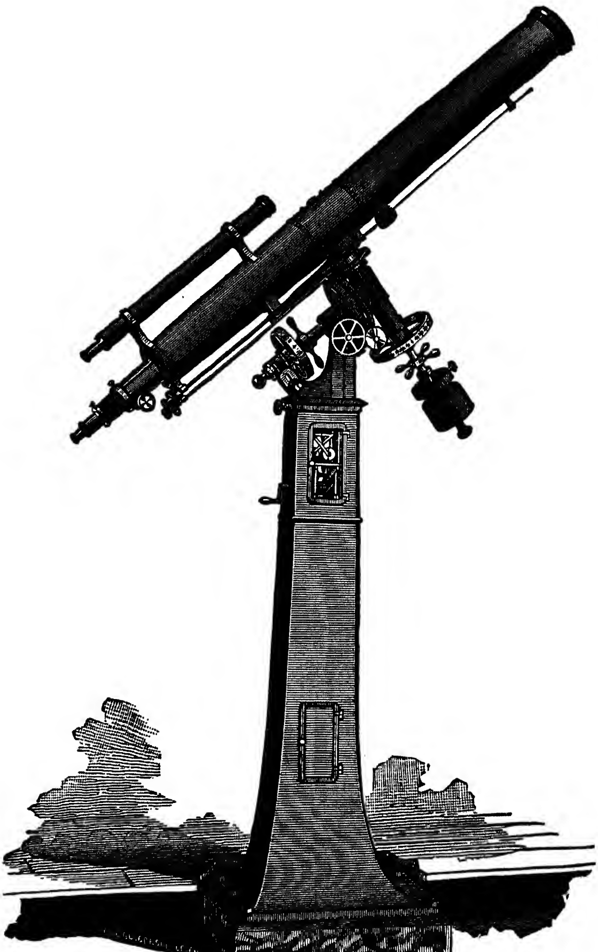

Figure 2; The Portable Equatorial.

made by ALVAN CLARK and SONS, and is a very fine one. The mounting is by WARNER and SWASEY, and I wish to testify here to its excellence of design and thoroughness of workmanship. A more convenient portable instrument could hardly be made. Its only defect is one which can easily be remedied—the lack of any means of adjustment in azimuth when temporarily mounted. For use in the field the upper section of the pier, containing the clock-work, is detached from the iron column on which it is mounted at the Observatory, and is bolted instead to an iron plate which projects beyond the clock section in a north-and-south direction. The projecting ends are secured by heavy lag-screws to the tops of two posts about a foot apart, the weight for the driving clock traveling in the space between the posts. All the screws and bolts fit so snugly that not the slightest adjustment in azimuth is then possible. To remedy this it would only be necessary to bolt the clock section to another plate, made adjustable with respect to the lower fixed one. When set up at Bartlett Springs the polar axis was found to be 12′ east of north, and this error was allowed to remain, as having no sensible effect on the position of the image for the time during which the instrument was required.

The clamps and slow motion screws in both right ascension and declination are brought down to convenient positions at the eye end.

The finder has an aperture of 2½ inches and a focal length of 20 inches. The centre of the field was originally marked by a small circle, half a degree in diameter, etched on a glass plate, but as this would have been a bad arrangement for viewing the Corona, I replaced it by two rather stout wires. The power of the finder is about fifteen.

The spectroscope used with the 6½-inch equatorial was kindly lent to the expedition by the Chabot Observatory (the Hon. FRED. M. CAMPBELL, Director; Mr. CHARLES BURCKHALTER, Assistant in charge), all of those belonging to the Lick Observatory being either too large or too small for the purpose. It has a collimator of 1.10 inches aperture and 10 inches focal length, and an observing telescope of the same aperture and 9.25 inches focal length. The prism is of moderately dense flint glass, and measures 1.75 inches on each side.

The arrangement of the apparatus throughout was almost exactly the same as that devised by Professor C. S. HASTINGS,

and used by him in his observations of the total eclipse of May 6, 1883. For a complete discussion of the theory of the instrument, review of previous spectroscopic observations, and statement of the facts on which Professor HASTINGS bases his forcible arguments in favor of the diffraction theory of the Corona, the reader is referred to his report published in a memoir* of the National Academy of Sciences, Vol. II. For the sake of completeness, and for convenience, a sufficient account will be given here to make the use of the instrument intelligible.

The following description of the essential part of the apparatus is given by Professor HASTINGS, on page 105 of the report above mentioned.

"The essential feature of the spectroscope, however, and that which adapted it to its particular purpose, was an arrangement of two total reflecting prisms just in front of the collimator slit. The office of these prisms was to form two virtual images, each being that of one half the slit, separated at their nearest ends by an interval equivalent to the diameter of the solar image in the equatorial used. The construction will be rendered evident by the

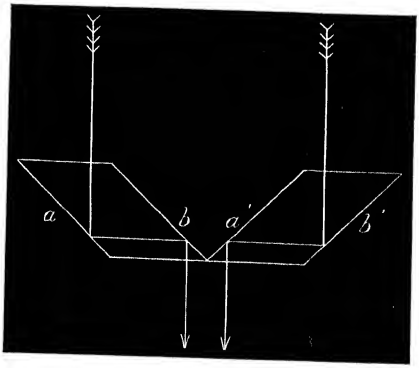

Figure 3; REFLECTING PRISMS FOR THE SPECTROSCOPE.

diagram, which represents a section of the apparatus by a plane *passing through the slit and the line of collimation.* The dimensions were so chosen that if the light from the right side of the solar image were transmitted, after two reflections by the prism $a' b'$, to the central point of the slit S, then light from the left edge of the solar image would be transmitted to S by the prism a b. It is evident that light from any other portion of the Sun would

* Report of the Eclipse Expedition to Caroline Island, May, 1883.

not fall upon the lens of the collimator, and, consequently, not appear in the spectroscope, but that light from the regions to the right and left of the Sun, up to a distance determined by the length (in this case 15′) of the slit, or the dimensions of the prism, would so appear; moreover, it is obvious that the spectra formed by the two halves of the slit would be adjacent. In fact, these two spectra, one of the region to the right of the Sun and the other that of the region to the left, were separated by a narrow black line about as distinct as the C line of the spectrum. Although all angles of reflection in the prisms were greater than the critical angle, the sides *a*, *b*, *a′* and *b′* were silvered, to avoid trouble in keeping them clean."

In my own instrument the diameter of the lunar image at the time of the eclipse was 0.718 inches. The faces of the prisms were 0.35 inches on the side, and consequently the distance between the obtuse angles was 0.70 inches. The image of the Moon, therefore, lapped over the outer face of each prism 0.009 inches, so that the two spectra were separated during the eclipse by a black band of considerable width (50″). The greatest distance from the limb of the Sun of points sending light through the slit was 17′, and this was also a little less than half the width of the field of the eyepiece.

The prisms were made and suitably mounted by Mr. Brashear from the dimensions which I furnished. They were covered with a cardboard screen (pierced by two apertures over the prisms), on which was drawn a square, just large enough to circumscribe the circular image of the Sun, to indicate the proper pointing of the telescope. The image of the Sun on this screen was of course a little out of focus.

The axes of the collimating and observing telescopes of the Chabot Observatory spectroscope are inclined to each other at a fixed angle of about 56°, which is greater than the minimum deviation of any part of the visible spectrum. The spectrum is brought into the field by rotating the prism, for which purpose a knob projects through one side of the prism box; and there are evidently two positions of the prism in which the spectrum can be seen: (1) with the refracting angle turned toward the collimator; (2) with the refracting angle turned toward the observing telescope. The dispersion is greater in the first position; the second position was chosen for the observations because the purity of the spectrum is greater and the whole spectrum is then within the

limits of the field. A small part of the beam transmitted by the collimator was, however, lost.

The positive eyepiece used has a magnifying power of 8.5 diameters. In its focus I placed across the centre of the field a narrow strip of mica, on which I had ruled and then painted coarse black divisions about one sixteenth of an inch apart. Ten of these divisions were included in the field of view, and the central one, which was ruled long and extended completely to the other edge of the scale, was adjusted to coincidence with the line separating the two spectra when the scale was placed transversely; that is, parallel to the FRAUNHOFER lines. The distance to which a line extended from the centre in either spectrum could thus be measured by the scale, one division of which was found to be 3′ 02″, or with sufficient exactness, 3′.

From the dimensions already given it is evident that the effective aperture of the collimating and observing telescopes was 0.84 inches, and the diameter of the emergent pencil 0.10 inches.

It will be seen, I think, from this description, that the apparatus I used was, on the principles pointed out by Professor HASTINGS in his report, of very high efficiency for the purpose intended. In this respect it differs little from that employed at Caroline Island.

The use of this apparatus during a total eclipse may be briefly described as follows: The slit being placed parallel to the direction of the Moon's motion and the image of the Sun properly adjusted on the slit-plate, the observer compares the lengths of the coronal lines on diametrically opposite sides of the Sun. For this purpose the 1474 line is most suitable on account of its superior brightness. If, then, the length of this line is a measure of the depth of a coronal atmosphere at the place occupied by the slit, it will only be slightly altered at the base as the Moon passes across the disc of the Sun; but if changes out of all proportion to the amount of the Moon's motion are observed, the conclusion is inevitable that the length of the line cannot be held to represent the depth of a real atmosphere, but is due (at least largely) to diffraction, since a change of such enormous magnitude in a material atmosphere is inadmissible. The diffraction, and consequently the length of the bright line, would be greater the nearer the disc of the Sun to the superposed edge of the Moon. The latter appearance is the one observed by HASTINGS, in 1883. Immediately after second contact the 1474 line was long on the east side, at the point where the Sun had just disappeared, and very

short on the opposite side, and at third contact the appearance was reversed. At the middle of the eclipse the lines were of approximately the same length.

SPECTROSCOPIC OBSERVATIONS DURING TOTALITY.

On the morning of the day of the eclipse I had put the instrument in perfect working order, and little remained to be done until just before the time of second contact. I then placed the slit in a parallel of declination, which was nearly in the direction of the Moon's motion, and centred the solar image carefully on the slit-plate. Mr. HILL was to keep the telescope pointed during totality, if any correction should be required, but the clock-work was driving so well that I was sure no attention would be necessary, and this proved to be the case. The prism had been set so that the 1474 line was just above the upper edge of the mica scale (which was parallel to the line), and the line of separation between the spectra was made to fall upon the central division of the scale. The slit had been carefully adjusted for parallelism, so that no difference could be detected in the two spectra, and, as in HASTINGS' observations, it was opened to such a width that the D line was just recognizable as double.

Up to fifteen minutes before totality the telescope objective had been covered with a pasteboard cap with small aperture, for fear of softening the cement with which the reflecting prisms were mounted (the slit-plate had, however, been placed in focus with the full aperture), and this was removed at that time.

Shortly after Mr. HILL gave warning of the approach of totality, I placed my eye at the spectroscope, but saw no change until a few seconds before second contact, when I thought the spectrum had a streaky aspect, as if bright lines were beginning to appear. Both sides were apparently alike. Then the narrow bright strip in the left hand spectrum disappeared, as the last ray of sunlight was cut off, and there remained a continuous spectrum, fading off on both sides of the dividing line, toward the edge of the field. At the same time the bright 1474 line appeared and above it a greenish blue line (probably F), the latter I think a little before the other, although it was not nearly so bright. The D_3 line was covered by the scale (or very close to its lower edge), and its behavior could not well be noted.

I was surprised at the brightness of the continuous spectrum, which evidently represented by far the greater part of the light

of the Corona. The mica scale was easily visible, and the colors of the spectrum were perfectly evident. Dark lines could be seen, but with difficulty. One just below the scale was undoubtedly D, another was probably *b*. There was also a somewhat streaky aspect, especially between the scale and the upper part of the field, which promised the appearance of other lines with a smaller slit-width, but as the shortness of totality made any experimenting with the adjustments rather hazardous, I did not try the effect of narrowing the slit. After returning to the Observatory I set up the instrument as nearly as possible in the same condition as when used during the eclipse, pointed it to the sky and cut off the light until the brightness of the sky spectrum was, according to my best judgment, the same as that of the continuous spectrum of the Corona, using as a guide the visibility of the divisions on the scale. Of course this experiment should have been tried immediately after the eclipse, when my recollection of the brightness was fresh; still, there was no doubt in my mind that the dark lines in the sky spectrum were much more easily recognizable than they were in the coronal spectrum during totality.

The 1474 line, on the other hand, although distinct, was not so bright as I had anticipated. At the moment when I first perceived it, the extension from the centre in both spectra was about the same, and was recorded as equal to four divisions of the scale. The left hand line, corresponding to the eastern limb of the Moon, where the Sun had just disappeared, almost immediately diminished in length, and a few seconds after the beginning of totality I made the record—"left 1½ div., right 3 div." The next record was, "left 1½ div., right 4 div." The lines faded away gradually from the centre, so that the exact points of disappearance could not be definitely fixed. They were of the same width in both spectra, showing that the parallelism of the slit had been satisfactorily adjusted.

After this there was no very marked change. The lines slowly grew more nearly equal—that on the right shortening, and that on the left lengthening, although they did not reach equality; and near the middle of the eclipse I suspended observations for a few seconds to look up at the Corona, as I have already mentioned in the general account of our operations.

On returning to the spectroscopic observations I found the appearance unchanged, and nothing was noted until perhaps two thirds of the total phase was over. The line in the right hand

spectrum, corresponding to the western limb of the Moon, where the Sun would presently appear, then began slowly to lengthen. While watching this process I heard Mr. McCraney call "*Look out!*" Then suddenly, a few seconds later, bright lines darted out in the right hand spectrum, from the centre clear across the field of view, as brilliant and as vivid in hue as the colored fires of pyrotechny. The apparition was so sudden and so unexpected that no estimate of their number or position could be made, but from the general impression they left on my mind in regard to spacing and color, they must have been mainly the lines of the chromosphere. The width of half the field being 17′, the length of the lines must have been greater than this. On the left hand, however, there was little or no change; the bright lines on the other side shone brightly for two or three seconds, then, as a dazzling band from the returning sunlight shot along the base of the spectrum, they vanished.

I have said the apparition of these lines was unexpected. This was because the slit was *radial* with respect to the Sun's image, and its intersection with the chromosphere would give rise to a very short line indeed. The spectrum of the "reversing layer" has always been observed, so far as I am aware, with a tangential slit, and the possibility of seeing it with the arrangement of apparatus that I used had not occurred to me.

An important part of the observations was to note, if possible, whether changes in the length of the 1474 line were accompanied by corresponding changes in the breadth of the continuous spectrum. As far as I could judge they were not—the continuous spectrum apparently suffered no change as long as I could see it; but I cannot attach much weight to this observation on account of its difficulty. The continuous spectrum extended the full width of the field on both sides, and any changes in its width would, therefore, manifest themselves as changes in brightness only, much more difficult to decide upon than the position of a point on a scale. It is quite likely that considerable changes might have escaped my notice.

Discussion of the Observations.

Just how far these observations are in accordance with those made by Hastings in 1883 it is not easy to decide. The phenomena recorded in the Caroline Island report are characterized by a regularity and symmetry which is lacking in those which I

observed and of which I have given a detailed account. They resemble each other most strongly in the behavior of the 1474 line at the beginning of totality, the line in both cases shortening rapidly at the eastern limb of the Moon after second contact had occurred; but at Caroline Island this line had an abnormal length in the beginning and shortened to meet the gradually increasing line in the spectrum of the opposite limb, whereas at Bartlett Springs the lines began with approximate equality and were decidedly unequal at the middle of the eclipse.

Toward the end of totality, with the exception of the gradual lengthening of the 1474 line in the spectrum of the west limb, there is little resemblance between the phenomena observed. At Caroline Island they were the same as at first contact, but in reverse order, as one might naturally expect. At Bartlett Springs the changes attending the end of totality seemed to have almost no connection with those near its beginning. If the standard of comparison were sure, we might say that the phenomena observed by HASTINGS were a perfect type resulting from the normal action of some law, and those I have described an imperfect example distorted by the action of some unknown disturbing cause. The most probable explanation of the apparition of the bright chromosphere lines at the end of totality and their absence at the beginning, is that in the interval a slight haze had collected over the Sun, and this, illuminated by the projecting chromosphere just before the instant of third contact, caused the appearance described. There is, however, no other evidence of the existence of haze at this time. The sky around the Sun looked clear immediately afterwards, and the negatives obtained by Mr. BARNARD near the end of totality are apparently as sharp as those made at the beginning. Nevertheless, in view of the fact that light, hazy clouds were floating around in the neighborhood of the Sun, such an occurrence is quite possible.

At first contact, the absence of haze was attested by the blackness of the band dividing the spectra and the fact that the bright 1474 line did not encroach on it. I have no recollection of the appearance of this band at the end of totality. The long and vivid chromosphere lines did not appear, then, at that contact for which the absence of haze is proven, although it is hardly necessary to say that such a startling apparition could not have been overlooked, and we may regard their appearance as an abnormal

phenomenon, which would not have presented itself under perfect conditions of observation.

Students of solar physics have not been able to accept the conclusion drawn by Professor HASTINGS from his observations (and many other considerations), that the Corona is wholly due to the diffraction of sunlight by the intervening Moon. It will hardly be disputed, however, that diffraction must play some part in its production, and that we have evidence of such action in the observations we have considered. The narrow and brilliant ring of light surrounding the Moon in the negatives of the Corona, a ring which is, as Mr. BARNARD has pointed out, always symmetrical with respect to the Moon, no matter at what stage of totality the picture was taken, is further evidence of the existence of diffraction. One conclusion that can be drawn from the observations of Professor HASTINGS and myself, is of an importance that can hardly be overestimated in its bearing on theories of the Corona; that since the length of the bright 1474 line changes during a total eclipse by an amount which is utterly disproportionate to the motion of the Moon, and which would involve on the ordinary explanation of its existence physical changes of such magnitude as to be entirely inadmissible, the length of the line with radial slit cannot be regarded as an index of the depth of a material atmosphere, but must be attributed to the effect of diffraction, which is probably increased under ordinary circumstances by the diffusive action of haze in the atmosphere of the earth. *We are thus freed from the necessity of supposing that there exists around the Sun a gaseous envelope of considerable depth.* It is hardly necessary to point out how difficult it is to reconcile the existence of such an atmosphere, the only testimony in favor of which is the appearance of these bright lines in the spectrum of the Corona, with other theories of greater probability and with well ascertained facts. Among the latter may be instanced the well known unobstructed passage of comets at perihelion distances far within the limits of the suppositious solar atmosphere.* In framing a theory of the

* The 1474 line has been traced by a number of observers to a height of 20′ or 54,000 miles above the Sun; by STONE, in 1874, it was traced to a height of 45′ or 1,200,000 miles. In my own observations, the greatest recorded height was 12′ or 325,000 miles. The distances from the surface of the Sun at which a number of well known comets have passed perihelion, are given below:

Comet of 1680	145,000 miles.
Comet of 1843	81,000 miles.
Comet of 1880	116,000 miles.
Comet I, 1887	280,000 miles.

The orbital velocity of the comet of 1843 at perihelion, was 350 miles per second.

Corona, such facts as these, which are simple and do not admit of doubt, must be given priority over appearances which may well be delusive and can be explained only on hypotheses at variance with one another in many important respects, and therefore more or less imperfect.

Spectroscopic observation furnishes us with many facts which cannot be reconciled with the theory of an extensive solar atmosphere. Two of the most important objections drawn from this source are given below. The first has long been recognized as especially perplexing.*

(1). The pressure at the surface of the chromosphere is shown by the spectroscope not to exceed that of a few millimetres of mercury, and this we must accept as the pressure due to an atmosphere from half a million to a million of miles deep, notwithstanding the fact that the force of gravity is twenty-seven times as great at the surface of the Sun as at the surface of the earth.

(2). "According to theory, as well as observation, the upper limits of the gaseous envelopes of the Sun ought to be ordered according to their densities. The material which produces the 1474 K line, and which may always be seen in the chromosphere spectrum, is, according to this criterion, as unmistakably denser than hydrogen as is magnesium vapor, or iron vapor; but if we accept the coronal spectrum as evidence of the existence of an atmosphere, we are, by exactly the same principle, driven to the conclusion that the 1474 K material is far less dense than hydrogen. The contradiction could not be more abrupt and inexplicable." †

It is hard to determine the magnitude of the part played by diffraction in the production of the Corona, assuming that it is not the sole cause. Professor HASTINGS has shown that one necessary consequence of diffraction would be an excess of brightness at any point where the limbs of the Sun and Moon were most nearly in contact; that is, at the eastern limb of the Moon immediately after the beginning of totality, and at the western limb just before its termination. An appearance of this kind, which occurs when more striking phenomena are impending, is very apt to escape notice. Mr. HILL was instructed to look for it, but failed to detect any change, and only negative evidence is afforded by the photographs. I must note here, however, that just such changes of

* YOUNG'S *The Sun*, p. 237.

† HASTINGS, Caroline Island Report, p. 118.

brightness are described in the report of Mr. P. McGee, a surveyor's assistant at Bartlett Springs, who had no knowledge whatever of coronal theories; with the difference that the changes observed by him extended over one third of the duration of totality reckoned from either contact, and were consequently slower than the diffraction theory would require.* The rapid shortening of the 1474 line after second contact, in my observations shows that there actually was a sudden diminution of brightness at the western limb of the Moon, but the change must have been very small.

Professor Hastings attributes the formation of coronal streamers and rifts to the existence of spots of greater or smaller brilliancy on the photosphere near the limb of the Sun, and the effect of the unequal illumination on the diffracted ring of light; the more minute detail of the inner Corona, he thinks, might be due to small irregularities in the edge of the diffracting screen, or limb of the Moon.

Any coronal form, depending upon the relative positions of points on the Sun and Moon, say a facula and a notch on the Moon's limb, would be altered by the motion of the Moon during totality; a streamer produced by the above supposed combination would, for instance, if near either pole, exhibit a motion of rotation. No changes of this kind were, however, noticed by Mr. Hill, who looked carefully for them, the Moon seeming to pass over the face of the Sun without affecting, in the least, any of the surrounding coronal details. The photographic evidence on this point is very complete. No eclipse has ever before been photographed with such a number and variety of instruments, distributed so widely in the path of totality. So far as the structure of the Corona is concerned, these pictures are identical, whether taken near the beginning or near the end of totality; at stations near the coast or far inland. The coronal forms even persist after the reappearance of the Sun.

We must conclude, therefore, that the coronal outlines and details are altogether independent of the Moon's position on the Sun, and their objective existence is rendered extremely probable. It would evidently be reduced to a certainty by the undoubted observation of the limb of the Moon nearest to the Sun when

*Similar changes of brightness have been recorded before, even as far back as 1733. See Grant's History of Physical Astronomy, p. 380.

entirely clear of his disk, since the Moon could only be visible under these circumstances by contrast with a bright background on which it was projected, and in which diffraction could have no part. I am not aware of any observation of the kind having been made up to the time of this eclipse, on which occasion we have two records of the visibility of the advancing limb of the Moon before first contact. Mr. Hill, observing with the finder of the 6½-inch equatorial stopped down to 1 inch and a neutral tint Steinheil sun-wedge held in the hand, saw the Moon's limb 2½ minutes or about 1¼′ before contact, and watched the approach of the limbs. A similar observation was made by Gen. Irish at Liegan, California. Mr. Barnard of the Lick Observatory party, however, observed with a 2½-inch telescope stopped down to 1⅜ inches, having a dark sun-glass attached to the eye-piece, and failed to see the Moon before first contact. In the reports of these gentlemen the observations above mentioned are described in full.

Assuming that the Corona is mainly a solar appendage having an objective existence, the explanation of its origin is simplified by the conclusion which we may regard as the chief result of the spectroscopic observations described in this report—that the extension of the bright coronal lines to a great height above the Moon's limb during a total eclipse does not necessarily imply the existence of a correspondingly extensive gaseous atmosphere around the Sun. All other facts point to the absence of such an atmosphere.

Under these conditions the white light of the Corona finds its most probable explanation in the presence of minute particles in space around the Sun, which may well be largely composed of the precipitated material forming the envelope which produces the general absorption of the light of the photosphere, ejected by outbursts of more than ordinary violence. All particles would reflect sunlight, but those in proximity to the solar surface would also be strongly self luminous, in a degree depending on their distance, and thus the light from particles near the Sun would give a nearly continuous spectrum, while that from particles more remote would give a spectrum more nearly resembling that of diminished sunlight. The appearance would in this harmonize with observed facts. That the amount of matter around the Sun is quite inconsiderable in relation to the space occupied by it is evident from the feeble brilliancy of the Corona, which, notwithstanding the intensity of the illumination of its particles, sends to us a smaller

total amount of light than the full Moon,* although its apparent area is considerably greater.

The explanation of the streamers and rifts of the inner Corona, on the supposition that they are mere rays and shadows in an enveloping mist, has been hitherto passed over without serious consideration, chiefly on account of the apparent curvature of the rays. To any one who has seen these rays and also the divergent beams of light from a surface of molten metal penetrating the smoky atmosphere of a foundry, the analogy is, nevertheless, very insistent. It is worth while to inquire whether this explanation is really untenable.

In the photographs and engravings of photographs that I have seen, the details of coronal structure may be roughly divided into two classes: (1) Rays or brushes of light proceeding from the limb of the Moon, in directions which may be radial or greatly inclined, the brushes often apparently made up of slightly divergent filaments. This structure was characteristic of the inner Corona in the eclipses of 1878 and 1889. (2) Curved, rounded or irregular masses of light, in general less sharply marked than the rays, and frequently of very indefinite outline. In this class may also be included the wings and outlying streamers of the outer Corona. The Corona in the eclipses of 1870 and 1871 appears to have been largely composed of these forms.

In the first place, let us consider whether sufficiently great differences of illumination can exist at the Sun's surface in order to give rise to the appearances presented by the inner Corona. If the surface of the Sun were of perfectly uniform brightness, no rifts or streamers in the surrounding mist would be possible. It is well known, however, that great differences in brightness do exist there, although they are not noticeable under ordinary circumstances on account of the dazzling brilliancy of the whole. They are best seen in photographs. In order to produce a definite ray a bright illuminating surface below some obstruction is necessary; a projecting point of greater brilliancy than the average, like a facula, would have no effect. This condition is met at the surface of the Sun. According to LANGLEY, PICKERING and other investigators, the Sun would radiate several times† its present amount of light if it were deprived of the envelope which produces

*See the photometric observations of Mr. LEUSCHNER, and observations of previous eclipses by others.

† From two to twelve times. YOUNG'S *The Sun*, p. 250.

the general absorption of the light of the photosphere. A mere rift in this envelope would probably therefore produce a difference of illumination in the external cloud-masses sufficient to account for the phenomena observed. If we admit that a preponderance of illumination in one direction can be produced in this way, at points near the beginning of these rays, we have an explanation of the fact that the polarization of the light in the Corona increases toward the Moon's limb.

Secondly, if an interior streamer could be shown to have an unmistakable curvature in the detail of its structure, or in any way contradictory to the supposition that it was produced by radiating beams of light, the explanation would of course fail. The streamers are frequently, perhaps usually, drawn curved, but we have only to look over the drawings (one of my own among the number) contained in the report on the total eclipse of 1878, published by the United States Naval Observatory, to see how fallible is the evidence of the draftsman. In one of these drawings, that of Mr. L. E. TROUVELOT, the polar rays are straight; in this, and according to the accompanying description, bearing a close resemblance to those of the Corona of January 1, 1889.* In the oil sketch of the Corona made at Bartlett Springs by Mr. YOUNT, which represents very satisfactorily to me the general appearance of the Corona as I saw it for a few seconds in an interval between spectroscopic observations, the polar streamers are shown as separate, each distinctly curving away toward the equator, but the true shape of the streamers, as shown in the photographs,† was entirely different. A number of other drawings, made by experienced observers, have already been published, and in some of these the polar rays are shown very much as in Mr. YOUNT's sketch.

It is on the photographs that we must rely for a decision on this point, and of these we have a great number taken during the last eclipse, of a greater degree of excellence than any hitherto made. The difficulties arising from the difference of brightness of the outer and inner Corona have been largely overcome by the

*Plate I, and p. 88. "These rays had a very great resemblance to those sometimes seen before sunset, when the sky is overcast with dense cumulus clouds, through the openings of which the sun's light is gently sifted and reflected from the particles in the atmosphere into soft rays of light diverging from their starting points. In fact, the rays of light of the Corona did not appear to have any real and material existence, but rather to be simply optical effects created by the reflexion of the light upon particles of matter dispersed in the solar atmosphere, after the manner of those of our atmosphere."

† See frontispiece.

rapid advance of photography since even the most recent of former eclipses, so that in one of Mr. BARNARD's negatives, for instance, we have an extension of the outer Corona nearly equal to that of the greatest obtained with long exposures, and on the same plate the details of the inner Corona almost down to the very limb of the Moon, the outlines of the prominences showing distinctly on the dimmer background of the coronal light. In a careful examination of the best photographs obtained by our own and other parties, I failed to detect any curved outline which could not be regarded as due to the intersection of a number of straight rays having different directions, or as the locus of equally bright points in space filled with mist or haze illuminated by such rays. In some cases there was an appearance of curvature caused by the fading away of one side of a beam of light more rapidly than the other side, as if the beam passed out of a cloud obliquely into comparatively clear space. *If there is any cause operating in the Corona which tends to produce a real curvature of these streamers, the probabilities are that it would show itself in some conspicuous example among the many streamers that occupy comparatively isolated positions, and not always appear where the detail is confused and the outlines of the streamers are more or less doubtful.*

That the rays are not streams of ejected matter is shown by the fact that among them are many sensibly straight and greatly inclined to the normal,* extending to a height of over 400,000 miles. This would, of course, imply an infinite velocity of the particles composing them. If we reject the explanation given above we are driven to the conclusion that the rays are produced in some way by electrical action, and while this may be true, there is at present nothing more that can be said of it.

In regard to the other coronal forms, whether straight, curved, or irregular, which are distinct from the inner streamers, we only require for their explanation the very natural supposition that the reflecting particles are unequally and irregularly distributed in space around the Sun, in which case the brightness would vary in a manner which might easily represent the appearance of the Corona as seen from the earth.

The *flat* appearance of the Corona finds no explanation on the theory proposed, but it must be remembered that it is after all only

*It will be remembered that under any circumstances of projection, a ray which does not appear radial to the Sun's limb cannot be normal to the Sun's surface.

an appearance, with hardly any reason for supposing that it represents the real arrangement of the Corona in space. On the contrary, a greater accumulation of coronal matter in the plane of the ecliptic would account for the greater confusion of details at the Sun's equator than at the poles.

We should naturally expect that the Corona, if formed in this way, would show some relation to the periods of maximum solar disturbance.

It is not too much to insist that for the purpose of testing the validity of these conclusions the details of the Corona should be studied in the original negatives, or in copies of them by photographic processes, and not in drawings, however carefully made. So many photographs were made during the last eclipse that they are sure to be widely distributed and to come into the hands of those most interested in such matters. The silver print by Mr. Barnard, which forms the frontispiece of this volume, shows admirably all except the finer details of the Corona; many of these are unavoidably lost in printing.

Summary of Results.

I give finally, a summary of the conclusions which are more fully stated above, and which must be regarded not so much as an attempt to form a complete theory of the Corona, in accordance with all the observed facts, as suggestions which may lead to the truth on which such a theory will some day be founded.

(1). The Corona is mainly due to light reflected from particles existing in space around the Sun. Near the Sun, however, the particles are largely self luminous. They are perhaps portions of the absorptive envelope of the Sun which have been ejected by eruptions of more than ordinary violence.

(2). The rifts, streamers, and other coronal forms are due to unequal and irregular distribution of this matter and to unequal illumination by the Sun.

(3). Superposed upon the Corona which is formed in this way, and blended in with it, is a more or less uniform ring of light caused by diffraction. This diffracted ring is necessarily rich in edge light of the Sun, particularly light derived from the chromosphere,* and to it is due the appearance of bright lines in the Corona at a considerable height above the sun.

*Caroline Island Report, pp. 123, 124.

(4). The sun is not surrounded by a gaseous atmosphere of great depth, that is, a depth which bears a considerable ratio to the solar diameter.

It is necessary to say that I have referred constantly to the material collected by Professor HASTINGS in his report, although in the light of information gained during the recent eclipse I have ventured to greatly modify some of his conclusions.

Very respectfully yours,

J. E. KEELER.

Professor EDWARD S. HOLDEN, Director of the Lick Observatory.

REPORT OF THE PHOTOGRAPHIC OPERATIONS.

By E. E. Barnard.

The photographic apparatus for our expedition consisted of a Voightländer lens one inch in diameter and nine inches focus, and an 8x10 Scovill camera box. The back lens of the Clark enlarging combination of the 36-inch equatorial was also available—the diameter of this was $1\frac{1}{10}$ inches and focal length 23 inches. The images produced by these lenses were manifestly too small to be of any special value for giving details of the Corona. They serve to show the outer Corona, to record the positions of stars and planets, and especially to give photometric data of importance. Experiments with the $3\frac{1}{4}$-inch objective of a telescope which is used to read the water scales on the distant reservoirs, showed that by cutting it down considerably a fairly sharp photographic image was obtained. The focal length of this lens was 49 inches. It was decided, therefore, to adopt this glass, stopped down to 1.75 inches, for photographing the inner coronal details, and to utilize the other two for the outer Corona.

A long wooden box, carefully lined with dull black cloth, and having a series of diaphragms inside, with a sliding adjustment in front, and fitted to carry a 5x7 plate-holder, was constructed for the telescopic lens. The back lens of the Clark combination, with a focus of 23 inches, was fitted with an extension tube to the Scovill camera, and a wooden box was made for the Voightländer lens—these two last were fitted to carry 8x10 shields.

Mr. Keeler had devised a polar axis, upon which these three cameras were to be mounted; this axis was driven by the clock of the 12-inch equatorial.

It consisted of two parallel strips of board with end pieces: inserted firmly in the upper end was a round piece of wood 4 in. in diameter. To this was clamped the sector belonging to the clock, while the clock itself was mounted under this upon a strong framework supported by four posts. A brass cylinder on the projecting end piece, turning in metallic boxes, formed the upper support of the polar axis, and the thrust of the lower end was received by

a socket in a heavy post set in the ground, the axis turning on a conical steel pivot. All woodwork was thoroughly saturated with linseed oil, to prevent it from warping. The long box-like body of this axis was partitioned off by step-like pieces at intervals of from 12 to 18 inches, so arranged that when the axis was in position their planes would pass 23° below the equator. The cameras firmly wedged in these spaces could be kept pointing at the Sun during totality. To this excellent arrangement is due the sharpness of the images of the Corona upon our negatives.

Having quite a number of plate-holders, it was deemed safest to fill them at the Observatory before leaving. As it was intended to standardize these plates for photometric comparisons of the Corona when we returned, a transverse portion at the end of each plate was carefully protected from the light of the Corona and the sky by a strip of ruby paper. It was decided to use the quickest plates: we therefore selected for our photographs the Seed No. 26, which from experience we had found to give the very finest results. Though these plates remained in the shields for an entire month before being developed, it was found that they had suffered no deterioration.

Leaving the mountain on December 16th, in fog and rain, we arrived at Sites, the termination of the railroad part of our journey, on the night of December 19th. We were delayed here two nights and a day, awaiting the stage.

At Sites, Mr. KEELER decided to remain over to hurry up the freight which was due through that point, while Mr. LEUSCHNER and I proceeded to Bartletts, forty-two miles, by stage. After riding the entire day through wind and rain in an open wagon—the "stage"—with no protection but our overcoats, we arrived after dark on December 21st, at Bartletts, wet through with rain and chilled with cold. The next day our freight arrived. We then selected for our station the croquet ground about one hundred yards southeast of the hotel. From this point the last contact could be observed while the lower limb of the Sun would be behind the crest of one of the mountains which walled us in on all sides.

No sky could be seen until the night of the 23d, when, through breaks in the clouds, we secured an observation of *Polaris* at upper culmination, laying off our meridian by the aid of a plumbline and a lantern. That night we again secured an observation of *Polaris* at western elongation, and our two meridians so laid off

agreed quite closely. The next day we proceeded to work, and dug the holes and erected seven posts—two for the equatorial and five for the polar axis. We received but little outside aid in this work. It was wet and raining most of the time.

Mr. Keeler arrived on the evening of the 24th, but continuous rain did not permit us to get our instruments in place until the 28th. Stormy weather had prevented any observations to determine the chemical focus of the 49-inch telescope lens before leaving the Observatory. Therefore, on the evening of the 29th of December, by wedging up the end of the box so that it would point to Rigel, a series of trails of that star were made on two sensitive plates, varying the distance of the objective before each exposure by one tenth of an inch. These trails were equally distributed on each side of the visual focus. Upon being developed they indicated a good chemical focus at one tenth of an inch outside the visual focus. This was therefore adopted, and the adjustable part firmly fixed at that point. By a careful measurement it was found that the distance from the inner surface of the object glass to the sensitive plate was 48.60 inches. The thickness of the objective is 0.61 inches.

The night before the eclipse was dark and threatening, and from the bad weather we had experienced all along, it seemed quite apparent that the eclipse would be lost in clouds.

Observations on the Day of the Eclipse.

The morning of January 1, however, dawned clear and brilliant. But as the day advanced hazy clouds began to appear, and at 11^h 30^m A. M. the sky was very dense in the south.

The first contact was observed through haze. Fortunately just before totality it cleared about the Sun, but shortly afterwards closed in again, and the fourth contact was observed through dense haze with the greatest difficulty. So close was our escape from total failure from clouds, that it seemed as if Providence had interfered in our behalf. Though the sky was not perfectly free from haze about the sun, it was very slight, and does not seem to have affected the observations or the photographs.

The morning of January 1st and up to near the time of totality was spent in completing the final adjustments of the cameras in position on the axis, and in examining everything to see that there should occur no hitch during totality.

Having to deal with the three cameras single handed—not having an assistant—they were arranged in as compact and convenient a form as possible, being so placed that both ends of the boxes could be reached with as little loss of time as possible in uncapping the lenses and changing the plate-holders.

The shields for the three cameras were placed in compartments of a box supported on its edge, and inclined with the polar axis so that each shield was conveniently close to the end of its particular camera. A lower partition in this box was similarly divided into three apartments to contain the shields as soon as removed from the cameras. By very slightly stooping, the plate-holders could be inserted in position, the slides drawn, and rising, the lenses uncapped for exposure. The arrangement was very satisfactory indeed, and allowed the best possible use of the time. The CLARK and the telescope lenses were exposed simultaneously by the right and left hands—the small VOIGHTLÄNDER lens was then given its exposure—the shields reversed or changed, and the process repeated.

Every precaution was taken to prevent the plates getting light struck. A black cloth tacked along the polar axis and reaching to the ground behind the box containing the plate-holders, thoroughly screened that side from extraneous light. A curtain of black cloth was also tacked to the box holding the shields. As soon as totality was over, this curtain was lowered and the box taken up bodily and carried into a darkened room where each shield was carefully wrapped in black cloth and subsequently transferred to an empty valise and carried by hand to the Lick Observatory.

When the Sun had narrowed to a thin crescent, in making a final examination of the cameras to see that the images were central and the clock driving properly, I noticed on the ground glass of the CLARK camera that the clouds some 10° to the west (left on ground glass) were tinged with prismatic colors.

The shields had been inserted in place and at the moment when MR. HILL, who was watching for the second contact with the finder of the 6½ in. called "time," the slides were drawn and the exposures began.

Three exposures were made with each camera. At the last exposure with the VOIGHTLÄNDER, the Sun came out before the cap could be replaced. Upon this plate where the Sun made its appearance is a row of bright, bead-like forms—the intense light

having caused a reversal of the image and produced a positive effect—these are taken to be "Baily's beads."

Immediately after totality I placed a fresh shield in each camera and stopped the driving clock, and at intervals of about two minutes made exposures on the solar crescent as quickly as uncapping and capping the lenses would permit. These were kept up for about fifteen minutes, it being intended to use the plates for orientation of the Corona negatives. However, as *Mercury* showed plainly on every plate exposed during totality, these were not needed. These orientation plates all gave a reversal of the image, *i. e.*, came out positives instead of negatives.

Return to the Lick Observatory.

The instruments were now hastily packed. Being extremely anxious to return, all the shields that had been used were packed in my valise, and I was ready to leave on the morning of the 3rd. Two passengers and a trunk having previously engaged every available space in the "stage," there was no seat for me. The men could not be bought off, nor would they leave their trunk.

After a great deal of persuasion—the roads being one mass of mud and the wagon frail—I secured the high privilege of riding on the trunk and holding my valise in my hands, with the clear understanding that I was to walk up all the muddy hills. It was uphill all the way to Sites!

We started in a heavy rain. It rained hard and persistently all that day. The stage had no cover and was open to the weather, and I had no covering but my overcoat. The trunk dashed wildly forward in going down each hill, and tried to escape backwards in ascending every elevation. The road was through *adobe* soil which, from the long continued rains, had become of the consistency and stickiness of molasses. For a good part of the way our wagon was up to the hubs in mud and water, and every few hundred feet we had to get out and free the wheels from the accumulated mire. As the horses drew their feet from out the sticky soil they caused reports like pistol shots. At last, tired out, drenched with rain, and bedaubed with mud, just as the night closed in, we reached Sites, and from thence the rest of the journey as far as San José was by rail.

Operations at the Observatory.

Upon the return to the Lick Observatory, some time was devoted to preparation for standardizing the plates. This delay, was utilized in endeavoring to find out how other photographs of the eclipse had fared, so that an idea could be formed of what we might expect from ours. It was soon found that the principal danger to be feared was a total loss of detail from the strong light near the Moon coming out so dense as to obliterate everything near the limb. It was, therefore, with the intention of restraining this necessarily over-exposed portion that the negatives were developed.

The developer was diluted very much, so that the image would be brought out very slowly, very little pyro was used, so that there should be as little density as would be consistent with a good negative. The images in developing came out soft, rich, and full of details—carrying the Corona to over 77′ from the Moon's center, and showing clearly the details to within less than 1′ of the limb.

The negatives had been numbered A, B, C for each instrument according to the order of exposure.

For the 49-inch and the Clark lens, the exposures were simultaneous and of the same duration—the exposure of the Voightländer lens came immediately after that of the others.

Negative A 49-in. and Clark exposed 1 sec. from 4th sec. to 5th sec. of totality.
Negative B 49-in. and Clark exposed 3 sec. from 30 sec. to 33 sec. of totality.
Negative C 49-in. and Clark exposed 4.5 sec. from 111 sec. to 115.5 sec. of totality.
Negative A Voightländer exposed 1 sec. from 7 sec. to 8 sec. of totality.
Negative B Voightländer exposed 3 sec. from 37 sec. to 40 sec. of totality.
Negative C Voightländer exposed 13 sec. from 107 sec. to 3 sec. after totality.

It was intended to give C of the Voightländer a long exposure, while C of the other two were receiving theirs, and while changing the shields for another round, but this was lost by the Sun coming out on it.

Upon examining these plates I have found, besides *Mercury*, which is clearly shown on all, only one star, that being *Sigma Sagittarii*. This star is shown on the negatives of the Clark lens. I have looked for *Jupiter* on the plates of the smaller camera, but as there was no sharpness except near the centre of the field, it was doubtless too much out of focus to show.

Actinic Intensity of the Corona.

The following are the results of an investigation of the photographic intensity of the light of the Corona upon five of the negatives. Three of these negatives were made with the 49-inch telescope, the other two by the Clark lens.

Before developing, the protecting strips were removed, and a series of standard squares put upon the plates by exposure to the light of a standard lamp at a distance of one meter. This lamp, which burns Colza oil, and is known as the Carcel burner, was kindly obtained for the Observatory by Professor E. C. Pickering, and is a fac simile of the standard lamp used at the Harvard College Observatory. Our results are therefore strictly comparable with their standard. The light from this lamp was admitted into the dark room through a diaphragn 0.077-inch in diameter, placed close to the lamp chimney—the directions furnished by Professor Pickering being carefully followed. A second's pendulum, swinging in front of this aperture, gave a succession of one second exposures. The series of standard exposures impressed on the plates was 1^s—2^s—4^s—8^s—16^s—32^s—64^s. These being upon the same plate and developed with the Corona, were directly comparable with it.

From the small size of our images, it was found to be impossible to compare large areas of the Corona with the standards. It was therefore decided to isolate small portions, and thus compare them. The following is the method of comparison: A piece of card with a good size pinhole—about one fiftieth of an inch in diameter—was placed over each standard square successively, and different portions of the Corona were examined through a similar hole. It was at first intended to use smaller holes, but it was found that areas less than these could not be so accurately matched, a considerable difference of density being required to make any apparent difference in the points. A paper mask, with a large circular hole, was placed over the negative, the Moon occupying its exact center. The card for examining the Corona had a pointer on one end and a scale of minutes of arc at the end containing the hole, zero being at the centre of the hole. The line through this scale, the hole, and the pointer, was placed centrally over the Moon's disc and the card slipped radially out over the Corona until an area was found which matched the density of the square under comparison; the distance of this area from

Plate III.

North

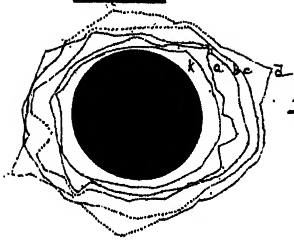

Fig. 1; 49in telescope (C).

East

South

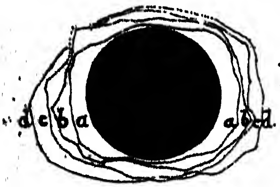

Fig. 3; (A) (49 inch telescope)

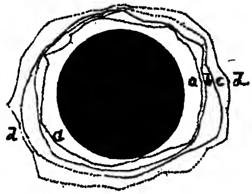

Fig. 2 (B)

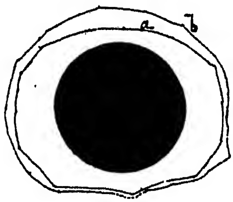

Fig. 4; Clark Camera (C)

Diagrams of the Actinic Intensity of the Corona, deduced from negatives by E. E. Barnard, — January 1, 1889.

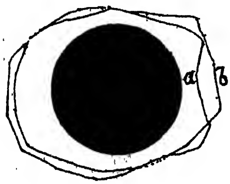

Fig. 5; Clark Camera (B)

the Moon's limb was then read on the scale and a mark made at the end of the pointer on the mask, in order to record the observation, as, for example: "*a* 5," which showed that on the line from this particular mark to the Moon's centre, and at 5′ from the Moon's limb, the density of the Corona was equal to that of square *a*.

In this manner a circuit of the Corona was made for comparison with square *a*, and so on with all the squares that could be compared. When the comparisons were all finished, the paper mask was removed from the negative and placed over a card, the centre being marked and a circle twice as large as the original image of the Moon described, as well as other concentric circles at every 5′ from the limb. A straight edge being laid over the Moon's centre and the mark on the paper, the position was recorded on the card by a dot, and the brightness by the letter of the corresponding square. After all the records had been transferred to the card, and after it had been duly orientated—using the line to the planet *Mercury* on the negative as a standard—each dot was pricked off on other cards, one card for the comparison of each square; a series of stencils was thus made, which could be used for making individual diagrams of *a*, *b*, etc., or for combining all in one diagram, to show the curves of different intensities. Thus the exact distance from the Moon's limb and the position angle of every comparison of brightness was known. In this manner have the five diagrams forming Plate III. been made from four hundred independent comparisons. The method, though laborious, is, I think, entirely free from prejudice, and it has the great advantage that the intensity of the Corona is directly compared with standard squares on the same gelatine film.

The comparisons of the two negatives made with the CLARK lens have been reproduced on the same scale as those with the 49-inch telescope. From the very small size of the original images, however, it was found impracticable to use all the squares, therefore comparisons were limited to squares *a* and *b*, the curves of which alone are given. At several points on the curve where it was not possible to locate a guiding comparison, the curve has been carried forward by a dotted line in general conformity with the outlines of Prof. HOLDEN's diagram, Plate II. At the poles of the Sun it is obvious that a continuous line means only that the bright streamers have the brightness indicated by the curve.

The following table gives the values of exposure to the standard lamp, which are merely referred to by letter. It also gives the values of the other squares that are incidently referred to:

$k=96^s$	$c=16^s$	$f=2^s$
$a=64$	$d=8$	$g=1$
$b=32$	$e=4$	

K on negative C of 49-inch telescope was produced by squares *a* and *b* having overlapped, and is assumed to be equal to an exposure to the standard lamp of 96 seconds.

Plates A, B, and C of the 49-inch and the Clark lenses each had standard square exposures impressed on them of 1^s—2^s—4^s—8^s—16^s—32^s—64^s.

Plates A and B of the Voightländer lens had each 1^s—2^s—4^s—8^s—16^s—32^s—64^s—128^s standard exposures; and C received exposures of 1^s, 2^s, 3^s, 4^s, 5^s, 6^s, 7^s, 8^s, 9^s, 10^s, 11^s.

From the readings on the paper masks I have constructed the following table, giving the mean light intensities for each of the four quadrants, referred to a meridian through the Moon:

Negative A—49^{in} Telescope. Exposure 1^{sec}.

Northeast.					*Southwest.*				
a	b	c	d		a	b	c	d	
3′.3	5′.4	5′.9	9′.1		3′.4	4′.7	6′.0	7′.2	
(5)	(7)	(7)	(9)	No. obs.	(6)	(4)	(6)	(6)	No. obs.
Southeast.					*Northwest.*				
a	b	c	d		a	b	c	d	
4′.4	3′.9	6′.6	9′.4		4′.4	5′.6	8′.5	10′.0	
(8)	(5)	(6)	(5)	No. obs.	(8)	(7)	(6)	(7)	No. obs.

Negative B—49^{in} Telescope. Exposure 3^s.

Northeast.					*Southwest.*				
a	b	c	d		a	b	c	d	
3′.9	4′.9	7′.8	10′.4		3′.1	4′.7	5′.8	8′.3	
(7)	(5)	(7)	(5)	No. obs.	(7)	(6)	(5)	(5)	No. obs.
Southeast.					*Northwest.*				
a	b	c	d		a	b	c	d	
5′.0	5′.7	6′.4	9′.6		3′.8	5′.6	8′.3	10′.9	
(9)	(7)	(4)	(5)	No. obs.	(6)	(6)	(5)	(7)	No. obs.

Negative C—49^{in} Telescope. Exposure $4\frac{1}{2}^s$.

Northeast.						*Southwest.*					
k	a	b	c	d		k	a	b	c	d	
4′.1	4′.8	8′.6	11′.3	12′.4		2′.3	4′.2	5′.9	10′.0	8′.7	
(7)	(11)	(5)	(6)	(9)	No. obs.	(5)	(7)	(6)	(5)	(6)	No. obs.
Southeast.						*Northwest.*					
k	a	b	c	d		k	a	b	c	d	
4′.7	5′.7	9′.3	9′.7	12′.5		3′.7	4′.9	7′.4	11′.3	13′.6	
(6)	(7)	(7)	(4)	(6)	No. obs.	(6)	(14)	(5)	(6)	(8)	No. obs.

Around the Moon to a distance of about 15′ or 20′ from the limb there is a soft, gradually fading glow, which I take to be atmospheric—this, in nearly all the negatives of the eclipse which I have seen has come out so strongly as to obliterate all the details near the Moon.* In developing our plates it was endeavored to restrain this as much as possible, the result being that the details close to the Moon are beautifully shown—the polar fans come out specially fine against this glow.

In the three 49-inch telescope negatives I have compared this glow at the distances of 10′ from the Moon's limb at the poles, with the following results:

NEGATIVE A.

South-Pole—10′ from limb = e.
North-Pole—10′ from limb = $\frac{d+e}{2}$ or possibly = d.

NEGATIVE B.

South-Pole—10′ from limb *just* perceptably *less* than e.
North-Pole—10′ from limb = $\frac{d+e}{2}$.

NEGATIVE C.

South-Pole—10′ from limb slightly less than d.
North-Pole—10′ from limb = d.

To show the intensity of the light of the sky I have selected a portion on each negative at 100′ from the Moon's limb—nearly the entire sky some distance from the Corona appearing uniformly dense.

NEGATIVE A.

100′ from Moon's limb the density is less than f, and would probably = $\frac{f+g}{2}$.

NEGATIVE B.

100′ from limb it is only just perceptably less dense than e.

NEGATIVE C.

100′ from limb the density about = $\frac{d+e}{2}$.

* That this glow is wholly atmospheric was conclusively shown by some photographs of the nearly full Moon which I made with four inches aperture of the 6½ inch equatorial, June 13, 1889. An exposure of seven seconds was given to a Seed 26 plate, and this was developed with the express purpose of bringing out any illumination of the sky that might be present about the Moon. A strong but softly diffused glow appeared about the disc for some 15′ or 20′—exactly similar to that shown in all the negatives of the eclipse of January 1, 1889. The presence of the slightest haze will, of course, strongly augment the glow.

As the density seemed uniform in all directions, I have not designated in which direction the 100′ density was located. Indeed, the sky was not dark during totality—a lantern was not needed—an ordinary newspaper could easily have been read without artificial light.

Collecting the tabulated information so far derived from the negatives, we have the following results, each of the numbers being the mean value for the entire circuit of the Corona:

Intensity of the Corona from Neg. A, 49 in.

	3′.89 from Moon's limb	= a.
	4 .90 from Moon's limb	= b.
	6 .74 from Moon's limb	= c.
	8 .91 from Moon's limb	= d.
	10 from Moon's limb S	= e.
	10 from Moon's limb N	$= \frac{d+e}{2}$.
Intensity of sky..........	100 from Moon's limb	$= \frac{f+g}{2}$.

Intensity of the Corona from Neg. B, 49 in.

	3′.94 from Moon's limb	= a.
	5 .24 from Moon's limb	= b.
	7 .06 from Moon's limb	= c.
	9 .79 from Moon's limb	= d.
	10 from Moon's limb S	= e.
	10 from Moon's limb N	$= \frac{d+e}{2}$.
Intensity of sky..........	100 from Moon's limb	$< e$.

Intensity of the Corona from Negative C 49-in.

	3′.69 from Moon's limb	= k.
	4 .89 from Moon's limb	= a.
	7 .81 from Moon's limb	= b.
	10 .60 from Moon's limb	= c.
	11 .81 from Moon's limb	= d.
	10 .00 from Moon's limb, S.	$< d$.
	10 .00 from Moon's limb N	= d.
Intensity of sky..........	100 from Moon's limb	$= \frac{d+e}{2}$

Intensity of the Corona from Negative B. CLARK.

6′.75 from Moon's limb = a, 16 comparisons.
7 .93 from Moon's limb = b, 15 comparisons.

Intensity of the Corona from Negative C. CLARK.

7′.59 from Moon's limb = a, 17 comparisons.
9 .65 from Moon's limb = b, 17 comparisons.

The following are the exposures of each plate to the Corona:

49-in. telescope.	Negative A=1s.	CLARK.	Negative A=1s.
49-in. telescope.	Negative B=3.	CLARK.	Negative B=3.
49-in. telescope.	Negative C=4.5.	CLARK.	Negative C=4.5.

The light ratios of these lenses were: $\frac{f}{a}$——

49-inch telescope 28. CLARK 21.

THE CORONA AS SHOWN IN THE NEGATIVES OF THE 49-IN. TELESCOPE. (See Plate II.)

NEGATIVE A.

The extent of the western wings of the Corona is about 45′ from the Moon's centre; the eastern ones extend 40′. There are at least twelve prominences on the east limb—one being within 34° of the south pole. Two fine prominences are beautifully shown at the west limb. The northern polar fan is traceable for fully 30′ from the centre.

NEGATIVE B.

This is full of beautiful details close to the Moon. There are at least five prominences on the east limb—the two large ones to the west are very conspicuous and sharp. The north polar fan can be traced at least 32′ from the centre. The streamers or wings to the northwest extend 60′ and those to the southeast 50′ from the centre.

NEGATIVE C.

This is an exquisitely beautiful negative—the soft, feathery details of the inner Corona, the delicate fan structures at the poles, and the great extent of the equatorial wings—over 77′ to the west—make it an extremely impressive picture.

To the west the edges of the streamers, or wings, soon branch out into a trumpet form, especially the northwest edge—between these two outlines, at some distance from the Moon, the coronal matter branches out and gives a fish-tail appearance to the Corona. Some of the rays of the north polar fan are traceable for 42′ from the centre of the Moon. The numbers in the following description refer to Professor HOLDEN's Diagram, Plate II.

The dark space 1 at the east of ray 2 is strikingly dark—apparently almost free of luminous matter clear to the Moon's edge. Two other strikingly dark spaces are seen in the fan at 113 and 108. These three stand out strongly in contrast with the general illumination. Another very singular object of this class is 65—an extremely fine black streak. These objects appear in all the negatives. A long and very slender bright ray (90) extends as a fine line for a great distance to the northeast. To the southeast a vast mass of the Corona extends out to between 55′ and 60′ from the Moon's centre, and at its base covers some 30° of the limb.

The beautiful symmetrical shape of the north polar fan is singularly contrasted with the irregular form of that at the South Pole.

From a lantern projection of a positive of this negative, I have made a careful tracing of the streamers, etc., and have, with a 5½-inch protractor, taken off the position angles of the bases of the prominent rays and the inclinations of these rays to a meridian through the Moon, and also the position angles of some of the prominences. The following tables exhibit the results:

NEGATIVE C.

Position angles of three conspicuous prominences:
113°.8, a small prominence.
246 .8, large broken prominence.
307 .1, large prominence.

Position angles of the bases of the bright rays and dark spaces constituting the north polar fan, and inclinations of the rays to a meridian:

P. A. Bases Bright Rays.	P. A. Bases of Dark Spaces.	Inclination of the Bright Rays.
°	°	°
336.0	333.4	52.6 W.
341.1	338.4	37.9
345.7	340.9	23.5
350.0	346.9	10.4 W.
355.7	352.9	5.0 E.
0.0	358.3	15.3
6.5	3.6	26.3
11.6	9.7	34.8
16.8	14.0	45.7
22.6	20.1	56.2
29.6	26.0	64.4
44.0	34.0	68.2
51.3	50.0	76.2 E.

Position angles of the bases of the South Polar Rays 1½′ from Moon's limb, and the inclination of these Rays to a meridian:

Position Angles of Bases.	Inclination to the Meridian.
°	°
210.7	61.6 W.
203.5	49.0
195.8	34.4
191.3	30.6
184.4	27.4
177.0	9.8 W.
173.0	15.1 E.
166.5	15.6
161.8	42.7
160.7	43.5
	45.1 E.

The following are the inclinations of the sides of the equatorial streamers to the meridian, etc.:

Northeast angle of streamer to meridian = 92° from N.
Southeast angle of streamer to meridian = 92°.5 from S.
Northwest angle of edge of streamer to meridian 84°.8 from N.
Southwest angle of edge of streamer to meridian = 90°.0.

The streamers near the Moon make a sharp curve towards the Sun—the following are the angles that these junctions make with the meridian:

Southeast, 60°.9.
Southwest, 63°.6.
Northwest, 65°.4.

In the negatives is a fine ring of intense light close around and lying on the Moon's limb, and symmetrical with it; this is quite sharply defined. A print made from the negative and greatly over-printed, brings this out strongly. As near as I can measure it—on the 49-inch negatives—it is $0^{in}.015$ in thickness = 29″. As this is symmetrical to the Moon in all three negatives, it is not, therefore, connected with the Corona, and evidently pertains to the Moon alone. It is probable that this is an effect of diffraction.

The Prominences.

A great number of prominences are shown on the negatives, all of these but two were on the eastern side of the Sun—these two, to the west were very large. From all the descriptions the prominences were intensely red, and consequently would have but little actinic power. They came out, however, strongly actinic, and appear brilliantly white on the most brilliant portion of the Corona—strikingly in contrast. The hydrogen line, near G, is known to be very strong in the spectrum of the prominences, and as this line occurs near that portion of the spectrum strongest in chemical effect upon the sensitive plate, it therefore indicates—as shown in the photographs—a high actinic power. One of these large prominences at 247° is seen—with a slight magnifying power—to have a large portion detached close north of its top.

The two western prominences are each about 45″ high in Negative C—49-in.

General Remarks Upon The Eclipse.

So impressive was the magnificent spectacle upon the crowd that had gathered just outside our inclosure, that not a murmur was heard. The frightened, half-whining bark of a dog, and the

click-click of the driving clock, alone were audible. When the Sun suddenly burst forth, an almost instant and highly surprised cackling of the chickens, that had hastily sought their roosts at the beginning of totality, would have been amusing, could one have shaken off the dazed feeling that possessed even himself at the sudden and unexpectedly rapid termination of the semi-darkness. My own feelings were those of excessive disappointment and depression—so intent was I in watching the cameras and making the exposures, that I did not look up to the Sun during totality, and therefore saw nothing of the Corona. I saw no shadow bands. One glance that I cast towards the clouds in the north, showed that they appeared of a sickly, greenish hue.

I had especially requested the stage driver who would be among the mountains on his return to Sites—to notice what effect the eclipse would have upon his two horses—and if he could, to notice the effect upon birds, etc.

He reported that he had reached the summit of the highest mountain along his road about ten minutes before totality. He waited at this point—as it grew dark, his horses became restless and began to quiver with intense excitement—one of these, a specially docile animal, as totality came on, turned its head towards him and looked appealingly, as if for protection, and so continued to look throughout totality, remaining quiet as if satisfied by the presence of a human being, while the other horse continued greatly excited throughout.

The driver looked into a small pool of water—from the recent rains—and said the Corona was more beautiful reflected there than in the sky. He saw the small birds flying hurriedly into the bushes by the roadside—seeking their roosts, and as the Sun again shone forth these small birds flew from the bushes in a confused manner.

A waiter at the hotel reported that a cow, grazing near him, showed no signs of fear, and continued to graze as if nothing were amiss—while the peafowls ran in a frightened manner for their roosts as darkness came on. He heard a dog howling during totality.

The Photographic Illustration. (Frontispiece.)

As we wished to illustrate the present report with a picture of the Corona as delineated on our negatives, and as it was too great an undertaking to make one thousand prints from our best neg-

ative, and as it was not practicable to have a good engraving made, Professor HOLDEN suggested that I make a series of negatives on an 8x10 plate from a glass positive of Negative C, 49-inch, so that by duplication in printing the labor might be reduced to a minimum. Acting upon this suggestion, I made two 10x8 negatives, upon each of which were sixteen exposures from a glass positive, which was selected from nearly a dozen experimental positives made from the original negative with various exposures and developments, in an endeavor to get the best possible reproduction. A Seed No. 26 plate was used for the final negatives. Sixteen equal apertures, 1x1.9 inches, were cut in an 8x10 paper mask as a guide; this guide was fastened to the back of the sensitive plate, as it was found that by putting it in front good contact was not secured. A thin mask of black paper, with an aperture as above, was properly adjusted on the film side of the positive. A piece of black cardboard, nearly as thick as the glass positive, had an aperture cut in it, in which the positive was fitted. More black paper completed the blocking out. The positive, masks, etc., were now placed in a 10x12 printing frame on a piece of plate-glass. The sensitive plate, with the guide on its rear surface, was then placed over the positive, and the frame held up to ruby light, and the image of the Corona carefully adjusted by the guide. The frame was now carried into an adjoining room, and at a distance of 49 inches from a kerosene lamp with white porcelain shade, an exposure of two seconds was made—this process was repeated for each of the sixteen spaces—great care being taken to give the same exposure to each, so that the negatives would be uniform; as each exposure was made, a speck of sticking paper was stuck on the back of the plate, in the aperture that had been exposed, so that no mistake should occur as to which aperture had been used. When developed, there was no appreciable difference in these negatives. Two of these plates were prepared, and from them sixty-three 8x10 prints were made which gave the one thousand silver prints of this report.

After considerable experimenting it was decided to adopt a different plan from the usual one in mounting and burnishing the prints. The following method, as it gave the best results, was adopted.

The prints, after being trimmed, were soaked for a few minutes in clear water; each print was then laid face down upon the smooth surface of a sheet of ferrotype plate, the water being pressed

from it and a little paste rubbed on; the stiff paper upon which they are mounted was then pressed down firmly on it—a guide being used so that the print should be symmetrically mounted. The prints were then laid aside for a half hour, under slight pressure, until partially dry, and then set upon edge in a warm room, where in from ten to fifteen minutes each print would drop from the plate, mounted and beautifully burnished. With a thousand prints this was a slow process, but the superior finish seems to warrant the time spent upon it.

In mounting these I have noticed a rather singular effect that is produced by the way in which the print is looked at. If it is held so that the western part of the Corona is uppermost, its visible extension is decidedly increased, and the fish-tail appearance of this part is seen to better advantage. Also, if the print is held with the North Pole uppermost, the fan at that pole can be better seen and traced further than in the reversed position. Indeed, with me, this rule holds good with respect to any part of the Corona; holding that portion uppermost it is best seen. The prints should be examined in moderately subdued daylight.

The negatives and prints I have made without any assistance, and the mounting, in this case the most tedious part, has also been done by me.

These photographs, though necessarily failing to show many of the details of the original negative, are exact productions from it, and have in no way been retouched—a process which, though an improvement to the appearance of the prints, would have vitiated their scientific value.

Observations of the Contacts.

My observations of contacts, I and IV, were made with a $2\frac{1}{2}$-inch telescope, reduced to 1.75 inch, and a power of about 40 diameters. Both contacts were observed through haze.

Contact I, $0^h\ 22^m\ 31^s.8$, Pacific Standard Time; probably 1 or 2^s late.
Contact IV, 3 7 16. 8, Pacific Standard time; very faint in haze.
Duration, $2^h\ 44^m\ 45^s.0$.

Conclusion.

It would seem from the remarkable success of all the photographic operations on the day of the eclipse, and the unreliability of drawings of the Corona, that it will hardly be of any consequence to attempt drawings of the Corona—where photographs

are to be made—unless, indeed, the sketcher simply wishes to try his skill to be afterwards compared with the actual thing as shown on the photographs. With the proper exposure—which, by the way, is secondary to a proper development—all that the unaided eye sees—and far more—both in extent and detail, can be secured on the photographic plate with even comparatively rude instrumental equipment. For the finer details some means of keeping the image stationary throughout exposure is absolutely necessary.

At this eclipse I should say that with 10^s exposure—using a quick plate, and with a light ratio of anything like 20 or 25, the full extent of the Corona can be secured. An exposure of two or three seconds will give all the nearer details.

The utmost care must be exercised in the development of the plate, for in this lies all the power of a successful representation of the Corona.

The development should begin with an extremely diluted developer, and with a very small proportion of pyro. This will bring the image out very slowly, requiring probably over an hour for the full development. The over-exposed portions will be restrained, and come out with comparatively little density, so that the most delicate details will not be lost, at the same time the fainter, outer portions of the Corona will appear. If, when completely developed, the negative is lacking in density, a little pyro added to the developer will then give the required amount.

It is best to use the most sensitive plates—I see no advantage at all in using a slow plate—for what cannot be shown on the quick plate certainly will not appear on the slow one.

I would here express my great obligation to Mr. Burnham, of this Observatory, for valuable advice in reference to both timing the negatives and in developing them. His remarkable skill in photographic work has made his advice singularly valuable.

And, in conclusion, I wish personally to express our sincere thanks for the great courtesy and kindness of Mr. Yount, who was unceasing in his endeavors to make each of our party perfectly at home at Bartlett Springs, and who made and presented to the Observatory three excellent negatives of our Station there.

Respectfully submitted,

E. E. Barnard.

To Mr. J. E. Keeler, Lick Observatory.

REPORT OF MR. C. B. HILL.

LICK OBSERVATORY, March 19, 1889.

To J. E. KEELER, *Esq., Chief of L. O. Eclipse Party:*

DEAR SIR: I beg to forward herewith a report of observations and notes made during the eclipse of January 1, 1889, at Bartlett Springs, Lake Co., Cal. These are recorded in full in a daily journal kept by myself after arrival at the station, from which this report is prepared.

I reported to you late in the evening of December 28, 1888, by which time you and the other gentlemen of the party (who had preceded me by a week) had very nearly completed the work of mounting and adjusting the various instruments.

TIME SIGNALS.

During the days preceding the eclipse I occupied myself assisting in the preparations; and calling time for the special rehearsals with the photographic and photometric apparatus, and for those of the whole party in concert. I also, in conjunction with Mr. LEUSCHNER, attended to the reception of the Lick Observatory Noon Signal, visiting the telegraph office for this purpose December 29, 30, 31, January 1, 2, 3, and 4. Mr. LEUSCHNER took the chronometer with him to the field station and assumed charge of it there; but we received the signals together each day they came through, he noting time on the chronometer directly, and I starting the second hand of a stop-watch, and making an independent observation—comparing carefully with the chronometer, before and after. In my record I have made frequent comparisons to control the rate of this timepiece (a "Centennial Chronograph" stop-watch, kindly loaned for the purpose by F. H. McCONNELL, Esq., of San Francisco), whenever it was depended upon for even a very slight interval of time. I also tested the readings of the watch completely around the seconds-hand dial by comparison with every beat of the chronometer, etc., etc.—noting "greatest deviation of stop-second-hand of watch not more than $0^s.2$, and probably less than that." The telegraph line to Bartlett Springs (a branch of the

Pacific Postal Telegraph-Cable Co.,) was in wretched condition between Colusa Junction and Sites, and the signals, when received at all, were very confused.

So far as we could determine, we only received the Observatory clock beats *direct* on the dates January 1 and January 3. On all other dates they failed to reach our station; but on January 2 they were repeated by hand at Colusa Junction, and on two occasions we managed to catch special signals sent from Sacramento at the request of "N." (probably NORMAN,) further up the line. My results are exhibited in the following table, and have been corrected for the error of the L. O. clocks, as published by Prof. SCHAEBERLE in No. 189 of the "*Astronomical Journal.*"

Corrections to M. T. Chronometer Negus 1719, on Pacific Standard Time, from Telegraphic Noon Signals.

1888–1889—Noon of.	Correction to Chronometer.	Depending upon.
December 31	(—8^{min} $32^s.2$)	Sacramento R. R. clock.
January 1	—8^{min} $33^s.2$	L. O. noon signal, *direct.*
January 2	(—8^{min} $31^s.7$)	L. O. noon signal, *repeated at Colusa.*
January 2	(—8^{min} $33^s.4$)	Sacramento R. R. clock.
January 3	—8^{min} $33^s.6$	L. O. noon signal, *direct.*

From which I deduce chronometer corrections for eclipse observations=

$$—8^{min}\ 33^s.2,$$

which may be in error as much as a quarter of a second.

OBSERVATIONS AT FIRST CONTACT.

Shortly before the predicted time of first contact I prepared to observe the occurrence thereof, using the finder of the 6½-inch equatorial, aperture 2.5 inches (stopped down to 1 inch), and power 15 diameters. I set the watch approximately to Pacific Standard Time, intending to start the seconds-hand at the observed instant, and then compare with the chronometer. Mr. KEELER commenced counting aloud by the chronometer, tapping every second, and calling the tens. At 0^h $28^m.5$ by his call I could trace "*the whole outline of the Moon's f. edge, distinctly and without any doubt whatever.*" I watched this for about two minutes, and could in that interval discern the approach of the two limbs. Then I turned my attention to the *Sun's* limb, to observe the contact, the instant of which was, I am certain, caught with very great sharpness; but

unfortunately, was not so noted. I started the watch (as I supposed), and took up the beat, still looking in the telescope; only to find, on again consulting the watch, that the hand pointed to zero. My interest in the phenomenon above noted probably accounted for this failure with the watch, which I took care should not occur again. The contact was noted almost coincidently with Mr. KEELER's call of "31," and I recorded

$$I = 0^h\ 31^m\ 01^s \text{ by chronometer,}$$
$$\text{or, } 0\ \ 22\ \ 27.8 \text{ Pacific Standard Time.}$$

I am quite certain of the observation *previous* to I contact, and between I and II (after completing my record above), could trace the Moon's limb 2′ or 3′ off the Sun's edge with certainty upon the apparent lower, *i. e.*, northern edge. I asked Mr. KEELER and Mr. BARNARD to verify this point with the same telescope. Mr. BARNARD was not satisfied in regard to it. Mr. KEELER confirmed the observation and noted the appearance *on both sides*, but more easily on apparent *lower*. I think the extremely low power used (together with a wedge instead of a sun-glass) was what made the observation possible: much as the dark limb of the Moon, when near First or Last Quarter, is discernible in a very small glass although lost under higher telescopic power. I believe it would have been almost possible to estimate the geometric contact.

TOTALITY.

The duty assigned to me by the chief of party, during the total phase, comprised:

(1.) Calling the instants of II and III contacts as a guide to Mr. BARNARD in his photographic exposures, and also as a warning to Mr. KEELER and Mr. LEUSCHNER in their work: thereby timing the duration of totality, etc.

(2.) Keeping the image on the spectroscope slit properly adjusted, should the clockwork of the equatorial not run perfectly (which it did, however).

(3.) Utilizing any moments, in the meantime unoccupied, for a study of the coronal rays, and any special appearances which might attract attention.

II AND III CONTACTS.

In timing the beginning and end of totality I was assisted by Mrs. C. B. HILL, who accompanied me on the expedition, and who had repeatedly practiced (since our arrival at the hotel)

noting the time by chronometer of two calls about two minutes apart. I also timed the duration with the stop-watch; Mr. McCraney, of the Lakeport "Avalanche," timing the same calls with his stop-watch, and also being instructed to call "Look out!" when totality had lasted $1^m\ 40^s$.

I called "Ten minutes," "Five minutes;" and then, about thirty seconds before totality, "Look Out!" The II and III contacts were announced by the call "Time!" and here I may record my belief that the actual occurrence of the two phases, the calls, and the record with my watch were practically coincident. The stop-watch I held read $1^m\ 56\frac{4}{5}^s$; (Mr. McCraney's, $1^m\ 57\frac{3}{5}^s$.)* Immediately after the total phase, I timed 2 minutes of chronometer time with the split-second hand of my watch, two trials giving, respectively, $2^m\ 00^s.2$, and $2^m\ 00^s.0$, from which I conclude that the watch readings require no correction.

The chronometer times of the two calls noted and recorded by my wife were:

$\text{II}=1^h\ 55^m\ 34^s.$

$\text{III}=1^h\ 57^m\ 31^s.$

Giving a result for the duration of 1^m 57s. Applying the correction from the foregoing table to reduce to Pacific Standard Time, these figures become:

$\text{II}=1^h\ 47^m\ 00^s.8 \quad \text{O—C}= +12^s.8.$

$\text{III}=1^h\ 48^m\ 57^s.8 \qquad\qquad +06^s.8.$

(The computed times being those derived by Professor Schaeberle from the data in the "British Nautical Almanac.")†

As the Sun's crescent narrowed to a mere line the light effects were very striking, the illumination was as if smoky, and the sky aptly described as "livid." Shadows of objects on the ground looked unnatural, the western border of each was indefinite, the eastern as sharply defined as usual. Some one called attention to *Venus* a long time before totality; later on a bright star showed just over the range to the south of us (afterward identified as *Jupiter*). I was not quick enough to catch any sudden diminution of brightness of the Corona immediately after the instant of II contact—as I had been warned by Mr. Keeler—it may easily have existed, and still have escaped my notice before I could withdraw the wedge and concentrate attention on that

* Mr. McCraney said that he had stopped his watch a little too late. J. E. K.

† Suggestions for Observing the Total Eclipse of the Sun on January 1, 1889.

point. Then I looked out, and saw the bright inner Corona instantly, and fish-tail streamers on either side, the general direction of the mass being inclined about 15° to the horizon, as roughly estimated at the time. (After the eclipse I made an outline sketch, from memory, to compare with the others who were devoting their time to that study. This is attached to my record book, and is only of use as showing the striking agreement among those at our station in regard to the general characteristics of the Corona in this eclipse.)

The Polar Rays.

Looking into the finder again, the polar rays, or filaments, were the most striking feature. I particularly looked for, but could not notice, any *irregular* curvature in them; they seemed generally like my recollection of Trouvelot's drawing of 1878, and more prominent on the south (*i. e.*, apparent upper) limb. They were not fan-shaped, however, and were—I should say from memory—either *radial* or else curved toward the Sun's equator.

Another point Mr. Keeler had requested me to look for was the possibility of any *apparent motion* of the polar rays. On this point, also, the evidence was negative so far as I studied it:—if there had been any displacement of the filaments at all commensurable with the Moon's motion, I think it would have been easily apparent, for almost as I looked I could see the Moon's limb uncovering a fine prominence on the south preceding quadrant, at a position angle of about 252°. Immediately under the point of this horn-shaped prominence was a detached portion, separated from the main body by over a minute of arc, and (with the low power I was using) looking very much like a stellar object. I was studying this object—the true nature of which did not occur to me until after totality—when Mr. McCraney's call of "Look out!" warned me to commence a watch for the emersion, which observation I have already quoted.

Visibility of Corona after Totality.

Immediately after calling III contact I looked at the Sun through the thin end of the dark wedge, and could follow the Corona on the eastern side for about three quarters of a minute, when the sunlight became too bright. The wedge was used in observing I, II, and IV; for III no shade glass was used with the telescope. The II and III contacts were very sharply observed,

and my duration of $1^m\ 56^s.8$ I feel certain of to within much less than $0^s.5$.

Mrs. Hill, after recording the time of II, sketched the outlines of the Corona as they appeared to her—not having had any previous experience in drawing, however. At the completion of totality the sketch was handed to Mr. Keeler without any change or addition.

Subsequent Notes.

Several parties remarked that the pea-fowl on the hotel grounds went to roost in the trees during totality, and that the cocks commenced crowing immediately on the reappearance of the first solar rays. I did not hear of any one noting the diffraction bands.

Mr. Yount and others spoke of feeling chilled through during the total phase: many bystanders noticed a perceptible lowering of the temperature. I did not feel this at all, myself. Compared with what I had been led to expect from the accounts of previous eclipses, the illumination during the total phase was exceedingly bright. I found I could read my watch face with the greatest ease at a distance of $1\frac{1}{2}$ or 2 feet from the eye.

Fourth Contact.

For this observation, Mr. Keeler removed the spectroscope of the 6-inch equatorial, and I noted the time of contact, using that objective, stopped down to 2 inches, and an eyepiece magnifying about 120 diameters. The record follows:

Sky very hazy, Sun's limb almost invisible at times. Started my stop-watch at what was, as nearly as I could determine, the complete disappearance of the notch: Sun's limb immediately faded out, and at the first subsequent view, $\frac{1}{2}^{min}$ later, there was certainly no trace. When my stop-watch had completed $1^m\ 00^s.0$, chronometer read $3^h\ 16^m\ 50^s.7$, hence $IV = 3^h\ 15^m\ 50^s.7$ by chronometer; $\pm$, say, 5^s. Or, reduced to Pacific Standard Time,

$$IV = 3^h\ 07^m\ 17^s.5$$

The cloudy state of the sky prevented any view of the Moon's limb projected on the Corona, as at I contact.

Summary.

Contact:	I = 0^h	22^m	$27^s.8$	P. S. T.	*Record uncertain.*
	II = 1	47	00.8	do.	*Good.*
	III = 1	48	57.8	do.	*Good.*
	IV = 3	07	17.5	do.	*Faint through clouds.*

Duration of eclipse = $2^h\ 44^m\ 49^s.7$.

Duration of totality (independently timed) = $1^m\ 56^s.8$.

The Moon was seen projected on the Corona $2\frac{1}{2}$ minutes before I contact; the Corona was apparent $\frac{3}{4}$ min. after III.

Conclusion.

The clouds which obscured the last portion of the eclipse became more threatening that evening, and the next day; and on the 3d and 4th there was heavy rain. The stage which left Bartlett Springs the morning of the 3d would only take one member of our party, and Mr. Barnard elected to travel in the rain. The stage which made the trip two days later carried us to Sites, a tiresome and almost dangerous journey of nearly twelve hours, and on January 9th, at noon, I reported again at the Lick Observatory.

In conclusion, may I be allowed to acknowledge the cordial spirit in which you enlisted our work; and which, with the fortunate clear sky on January 1st, and the great courtesy of Mr. and Mrs. G. W. Yount, at the hotel, served to outweigh the hard journey and the wretched weather, and to make the L. O. Eclipse Expedition to Bartlett Springs a very pleasant memory.

Yours faithfully,

Chas. B. Hill,
Assistant Astronomer, L. O.

REPORT OF PHOTOMETRIC OBSERVATIONS.

By Mr. A. O. Leuschner, Cand. Phil.

I. The Photometer–Apparatus.

The arrangements for the photometric observations were made according to a plan laid out for me by Mr. Keeler, chief of party, the object being to compare the diffused light of the Corona with the diffused light of a standard candle, by means of the Brashear wheel-photometer of the Lick Observatory. As a diffusing medium common white cardboard was used, such as is employed in mounting photographs. Two sheets of this cardboard, 4 inches square, were attached to two wooden plates of the same size. We shall denote the plate from which the light of the Corona was diffused by A, the other one by B. The plates A and B threw their light through small holes, 1 inch in diameter, from opposite sides, into a flat dark box (25x16 inches) on two vertical, rectangular, silvered mirrors *a* and *b*, which were inclined to each other at an angle of 90°, and which were of the same height as the box. The free edges of the mirrors were fixed to the top, bottom and side of the box respectively, while the vertex of the angle between the mirrors lies in the interior of the box, towards the observer. The circular images on the mirrors *a* and *b*, of the plates A and B, were examined through an opening, 1 inch in diameter, in the long front side of the box, opposite to the vertex of the angle of inclination.

In order to protect the images from any extraneous light, a wooden frame was placed around the mirrors, with holes corresponding in size and position to those in the box. All of the interior work was painted dull black. On the left hand side of the box, between plate B and the box, and close to it, was placed a Brashear wheel-photometer, to modify the light from the plate B. The box as well as the photometer rested on a common table (6 feet long and 4 feet wide), while the plates were connected with it by means of supports, as will be seen hereafter. It was necessary to elevate the dark box on a stand in order to bring the hole in the left hand side opposite to the upper portion of the

photometer-wheel. The plate B was set perpendicular to a long (12.5 feet) board painted black; then it was turned until it made an angle of 45° with the longest dimension of the board. The end of the board on the table rested on a wooden block, high enough to bring the centres of the plate B, the mirror *b*, and the hole on that side in a straight line, the continuation of which of course passed through the corresponding centres on the other side.

As the board (which ran parallel with the sides of the box) bent downwards in the middle by its own weight, it was supported by a post and made level. On this board rested a candle-lantern, made of a black box with a glass front. The box with the candle could slide easily along the whole length of the board. By this relative position of candle and plate, the angle of incidence of the rays of the candle on the plate B was made = 45°, and as the plate made an angle of 45° with the straight line through the centres of the mirrors, plates, etc., the angle of emanation of light of the plate B on the mirror *b*, was also 45°. Any other angle, of course, would have answered the purpose, if the same inclination had been given to plate A. The brightness of the circular spot in the mirror *b*, due to the light of the plate B, could be changed in two ways, viz.: (*a*), by cutting off more or less light with the photometer, or (*b*), by varying the distance of the candle from the plate. The distance of the centre of this plate from the hole in the box was $14\frac{5}{8}$ inches, and from the ground 3 feet $9\frac{1}{8}$ inches; the corresponding distances of the plate A on the right hand side being the same.

By the plate A, as stated above, the light of the Corona was to be diffused. In order to get here the same angles of incidence and emanation as before (45°), this plate was fixed at angle of 45° to an axis around which it could be revolved. This axis then was set perpendicular to a little vertical post, resting on a board projecting from the surface of the table. Thus, by turning the table, until the object which was to be examined was in the plane of the right-hand side of the box, and then revolving the plate around its axis, until the line joining the object and the centre of the plate made an angle of 45° with the plane of the plate, the angles of incidence and emanation were here made the same as before (45°). The easiest way to effect this was by laying a piece of glass on the plate and turning it until the image of the object itself was seen in the mirror *a*. The spot in the mirror *a* (due to the Corona), was then to be compared with the one in *b* (due

to the candle) by diminishing or increasing the brightness of *b*, in one of the above stated ways, until both spots were of the same brightness.

The day before the eclipse, December 31, 1888, the table and the plate A were adjusted in the stated manner for the time of the eclipse. To be sure that the spots would show a maximum amount of light, I replaced at the same time the cardboards by regular mirrors which at once threw images of the candle and Sun in the centrefields of *a* and *b*. Really this precaution was not very important, as it has been shown by BOUGUER and others that, if the angles were somewhat out, it would have affected the observations by a small percentage only. Besides there was no danger that the Corona would run out of the field during totality, as it took the Sun about ten minutes to pass across the field of view. The candle used was a simple wax-candle. It was compared afterwards with the standard lamp of the Lick Observatory. During observations the centre of the flame was at the same height from the board as the centre of plate B. After having been lit the candle increases in brightness for about 1½ to 2 minutes; after that it burns quite uniformly for 5 minutes. The candle and object are always kept on different sides of the apparatus, so that the plates A and B turn their backs to the candle and object respectively. By this arrangement each plate is protected against the light shining on the other. To prevent the rays of the Corona from striking the glass of the lantern and being reflected back on the plate B, a screen was put up against the Sun. Another screen was put up between my photometer and the equatorial and polar-axis of the other observers, as there was a possibility that they would use lanterns during totality.

From what has been said it appears that the plate B diffused not only the light of the candle, but the combined light of the candle and a certain portion of the sky. Also on the plate A there was not the light of the Corona alone, but the combined light of the Corona and another certain portion of the sky. The screens, however, should not have been used, as they made the computation of the amount of skylight that fell on each plate more complicated.

Although I arrived at Bartlett Springs in the evening of December 21, 1888, I could not get the apparatus in position before Friday, December 28, on account of the bad weather. From this date I made almost daily observations for practice. It remains,

however, before I give an account of these preliminary observations, to state something about the construction of the wheel-photometer. The photometer was manufactured by J. A. Brashear, of Allegheny, Pa. The principal part of it is a vertical wheel A, 12 inches in diameter, attached to a horizontal axis which rests on two vertical posts (1 foot high) on a heavy iron plate. At one end C, the axis widens out into a wheel C, 1 inch in diameter, which is geared into a larger one B below it, 8–9 inches in diameter, to the axis of which a handle H is attached. Thus only a few rotations of H, (which can be turned by hand or the foot) are sufficient to set A in rapid motion. The wheel A consists of four thin discs, which can slide on each other around their common axis. Near to the edge of each disc a ring (r) of sectors is cut out, the inner diameter of which is $6\frac{3}{4}$ inches, the outer $10\frac{3}{4}$ inches, thus leaving a small solid ring ($\frac{5}{8}$ inches wide) at the edge of each disc. There are ten equal open sectors in the rings (r), which bear to the remaining closed sectors the ratio 3–1. Thus the sum of all the closed sectors in each disc $= \frac{1}{4}$ of the ring, or by means of each rotating disc 25% of light shining through its ring of sectors can be cut off. By revolving the next disc on it, until the two sectors form one continuous sector twice as large, 50% can be cut off, by the rotation of the combined discs, with 3 discs 75%, and by means of 4 discs we can cut off all the light.

The revolving of these discs on each other, or better, *the setting of the photometer-wheel to a certain percentage*, is arranged by the maker in a very ingenious way. At the other end C′ of the axis is a second handle by means of which a rod can be pulled out of or pushed into the axis. The axis on this side is widened out into a cylinder, in which two spiral slots are cut opposite to each other. One of the discs is fixed to this cylinder. To a collar which can rotate freely about the rod in the axis two opposite pins are attached, which travel in the slots of the cylinder. Thus by pulling out the rod the pins will force the cylinder and hence also the disc attached to it, to revolve. If we start from the position, in which the closed sectors of the four discs lie on top of each other, then by pulling the rod out the closed sectors of the first disc will move off from the others. As soon as it has come off entirely, it will take the next one along and so on, until the whole wheel has been closed. The great advantage of this arrangement is, that the discs can be adjusted while the wheel is turning. In a similar way we can open the wheel again as far as desired, by pushing

the rod in. A scale on this side, graduated to 2%, gives the reading for any position of the discs on each other. The handle is provided with a clamp. The reading of the scale for any setting of the discs must of course correspond to the ratio of the sum of the open sectors of the wheel to the whole area or, if all the sectors are exactly equal, to the ratio of any open sector to any whole sector (including open and closed part).

The accuracy of the graduated scale was examined in the following manner: The photometer was placed in front of a window. Then a paper disc of the same size as the photometer-wheel was placed flat on the wheel. The instrument was clamped at every 10 per cent as shown by the scale. The open sectors then showed through the paper. Along the edges of the apertures lines were drawn on the paper with a sharp pencil. This was done with all the sectors at every setting. Then the angles of the open and whole sectors were measured on the paper. The ratio of the mean of the angles of the ten open sectors to the mean of the angles of the whole sectors would give the observed percentage. The scale was examined in this manner four times. The following table shows the results, as they were obtained from the four paper discs:

Setting. Per cents.	Observed percentage from I.	II.	III.	IV.	Mean.	P. E. of one determination	P. E. of mean of 4.	Scale—Observed. *Per cent.*
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	± 0.0
10	10.9	9.4	9.3	9.1	9.7	0.6	0.3	+ 0.3
20	20.7	19.9	19.5	19.1	19.8	0.5	0.2	+ 0.2
30	29.9	29.9	29.4	29.6	29.7	0.2	0.1	+ 0.3
40	39.6	39.7	38.9	39.4	39.4	0.2	0.1	+ 0.6
50	50.0	49.5	49.0	49.4	49.5	0.3	0.1	+ 0.5
60	59.9	59.7	58.5	58.4	59.1	0.5	0.3	+ 0.9
70	68.9	68.3	68.0	68.2	68.4	0.3	0.1	+ 1.6
76	75.5	74.4	74.2	74.6	74.7	0.3	0.2	+ 1.3
Whole sectors..	35.9	35.85	35.87	35.95	35.9	0.0	0.0	+ 0.1

A curve was drawn from which the corrections to be applied to observations, can be taken, the abscissæ corresponding to the photometer readings and the ordinates to the values given in the last column. The photometer was constructed at the suggestion of Mr. Keeler, and answers its purpose exceedingly well. It is an improvement by Mr. Brashear on a somewhat similar instrument in the possession of the Allegheny Observatory.

II. Observations Made Before January 1st, 1889.

[Extract from original record.]

Friday, Dec. 28, 1888. Trials made and defects discovered. Everything made more solid. Candle in box had not air enough.

Saturday, Dec. 29, 1888. First recorded trial of photometer. A common candle was used and compared with a lantern placed on the ground at a little distance (about 14–16 feet) from the plate A. In these observations I was kindly assisted by Mr. F. B. Staples, who turned the photometer-wheel. The candle I used was very unsteady. My conclusion was, that if the light of the Corona should be very faint, enough light could be cut off. The light of the candle can be reduced to about $\frac{1}{10000}$ of its brightness at a distance of 1 foot.

Sunday, Dec. 30, 1888 (in the morning). Everything adjusted. Table put in position by bringing Sun in plane with side of box. Plate A adjusted and marked for the position, in which it throws the light of Sun in centre of field at time of eclipse. The night from Saturday to Sunday, was the first clear night. The Moon at 5 A. M. could not be observed.

In the evening the candle was again compared with lantern on ground for practice. Mr. Barnard at the same time working at his apparatus. The light of his lanterns affects observations. Screen put up against the other instruments. Candle-box covered with black cloth inside.

Monday, Dec. 31, 1888. The observations of Sunday were better than those of Saturday. Light much steadier, but often observations affected by lanterns, as they were carried past by other observers. I do not think the observations made up to this date are good, as too much affected by unforeseen circumstances. Screen put up against Sun to prevent rays of Sun from striking lantern and being reflected back on plate B. Instrument and table again adjusted at time of eclipse. Before and after time of eclipse the party rehearsed the entire programme of operations, being timed by Mrs. Hill. Mr. Staples again turned the photometer-wheel.

Besides these photometric observations I made a number of time comparisons (mean time chronom. 1719 and time signals) from December 31, 1888, to January 3, 1889, which are given in the annexed table. Prof. Schaeberle has published in the "Astr. Journal," No. 189, 1889, the corrections to be applied to them to

reduce to Pacific Standard Time. The third column contains the corrected signals or correct Pacific Standard Time.

TABLE I.

Date.	Pacif. Stand. Time. (Signals.)	Pacif. Stand. T. (Corrected Signals.)	Chron. Time. (Mean Time chron. 1719.)	Chronom. correction.	The signals come from.
1888.	h m s	h m s	h m s	m s	
Dec. 31	0 11 0.0	0 11 0.35	0 19 32.90	−8 32.55	Sacramento (repeated).
1889.					
Jan. 1	0 0 0.0	23 59 59.82	0 8 33.00	−8 33.18	L. O. (direct beats).
Jan. 2	23 55 0.0	23 55 00.01	0 3 33.30	−8 33.29	?
Jan. 2	0 19 0.0	0 19 00.01	0 27 33.20	−8 33.19	Sacramento (repeated).
Jan. 3	0 0 0.0	0 0 0.00	0 8 33.25	−8 33.25	L. O. (direct beats).

Accordingly the chron. corr. at the time of each of the four contacts was $-8^m\ 33^s.2$.

III. How the Observations at Totality were made.

The board, on which the candle rested, was about 12.5 feet long, but only about 11 feet of it were left free for the candle to slide on, after it had been fixed to the apparatus. As I expected the light of the Corona and sky to be very faint, I set the candle before totality at a distance of about 11 feet from the reflecting plate. But the light was very much brighter than I expected it to be. Even by letting all the light of the candle through the photometer (about $\frac{80}{100}$) I could not get an image bright enough to compare with the combined light of sky and the Corona. So I jumped up and set the candle about 1 foot nearer to the plate. But even then I did not get a satisfactory image. So I had to change the position of the candle-box again, setting it at the distance first recorded. I then got the first readings. After having obtained three readings with this position, I changed it, first having made a mark with a red pencil on the board at the edge of the candle-box. In this manner I got seven readings with three different distances. After the eclipse I took the glass of the candle-box out, to save it for further experiments. I also saved the white cardboards, which were used for diffusing the light of the candle. I did not see the Corona at all, as the screen, put up against the Sun, hid it from my sight. I was too occupied with my observations to look around the screen. Mr. STAPLES had the kindness to turn the photometer during totality.

IV. Copy of Original Record and Memorandum.

Tuesday Morning, Jan. 1, 1889. Indications good. Sky a little hazy. Board, on which candle slides, painted black. New diffusing cardboard put on the plates. Candle lit at 11 A. M., to burn down. $12^h.00$, candle changed, because not steady. Everything ready for observation. $1^h\ 30^m$ lanterns lit. $1^h\ 40^m$ candle in box lit. Eyes shaded from 10^m before totality until Mr. Hill called "Look out."

Observations on Brightness of Corona made during Totality.

Table II.

Set.	I. Distance of Edge of Box from Plate.	II. Distance of Candle from edge of Box.	Distance of Light from Plate.	Photom. Readings.			Mean.
				First.	Second.	Third.	
			=I+II.				
I..	$9^{ft}\ 3\frac{3}{8}^{in}$ $(8'1\frac{3}{8})$?	$3\frac{7}{8}^{in}$	$9^{ft}\ 7\frac{1}{4}^{in}$	74	68	67	70
II..	$6\ \ 4\frac{1}{8}$	$3\frac{7}{8}$	$6\ \ 8$	(60)[a]	34	38	36 (44)
III..	$4\ \ 1\frac{4}{8}$	$3\frac{7}{8}$	$4\ \ 5\frac{3}{8}$	28	--------	--------	28

(a) Rejected at time. See original Memorandum.

Immediately after totality I wrote down the following notes:

"In 2d set (second horizontal line of the table above) the brightness seemed to change suddenly. Comparison was very difficult, as the one of the images was perfectly bluish; the other (candle) reddish. I think the first set (first horizontal line of table) is very good; also, *2* and *3* of 2d set, and the last observation. The first observation of II may also be very good, but I do not trust it so much as the others. Immediately after the eclipse the marks of the distances of the candle were looked for, and the first mark was not very well defined, but the 9′ 3⅜″ distance is, according to my opinion, correct. The other measurement put down, 8′ 1⅜″, is the distance of a scratch on the board, which may perhaps be the correct distance; but I think the first distance given is the one. The distance of the centres of the mirrors from the box was 14⅝″. The candle seems to have increased *slightly* in brightness during totality. The board on which the candle slid was painted black, and the red pencil did not leave much color on its surface." Afterwards the following notes were added:

"At about 4 P. M. January 1, 1889, the following measurements were made: Candle-box=8x10 inches and 16½″ high. Board

(on which the candle was moved), 12′ 9″ long. Centre of diffusing plates, 3′ 9″.5 above ground. About the last observation (third horizontal line of table), I may add that I do not think I was quite through adjusting when Mr. HILL called "Time." In the afternoon I examined the board again. After careful examination I detected traces of red color in the first mark (9′ 3⅜″)."

Before reducing the observations it was to be decided which observations should be used in the reductions, as there might have been some doubt on three points:

1. Which of the two recorded distances in the first set was the correct one?

2. Should the first observation at the second distance be used?

3. Should the last observation be used?

1. On the day of the eclipse I believed that the distance 9 feet 3⅜ inches was the correct one, as I detected only at that point traces of red pencil on the blackboard. Where, then, did the other mark come from? It will be remembered that I only succeeded in getting comparisons after having changed the position of the candle twice. The marks were made before the observations were taken. The farther mark of the two undoubtedly indicates one of the distances where I did not succeed. Therefore I have no doubt that the nearer distance (8′ 1⅝″) is the correct one.

2. After the first comparison of this set had been recorded (the instrument still being clamped), I noticed that the images were not of equal brightness any longer. Therefore I put that observation in brackets in the original record. The two next comparisons, agreeing among themselves, gave readings differing quite a little from the first one. It cannot be decided whether the first observation, or the last two, or *any* have been affected by unforeseen circumstances, or whether it was simply an error of observation, or whether there was really a change of brightness either in the coronal light or in the candle-light. Other observers say that they did not notice any change in the Corona. The foregoing considerations lead me to use the mean of the three observations.

3. As I do not think that I was quite through adjusting when Mr. HILL called "Time," and as two sets are quite sufficient for the reductions in hand, I have preferred to omit the last single observation, instead of including it with a very small weight. It is, however, reduced for comparison with the others.

The unit of light adopted in the reductions is the light of a candle after having passed through the glass of the candle-box,

the candle being at a distance of one foot from the plate B. This simplifies the reductions, as it does away with the necessity of determining the coefficient of absorption of the glass. The light of a standard lamp and the Moon will be subsequently determined in terms of the same unit. The constant errors which arise from the difference of color of the candle and of the Corona (or Moon) are not to be avoided.

The following table gives the quantities on which the reductions are based. The observed photometer-readings have been corrected for the errors of the scale:

TABLE III.

Set.	Distance of Candle = d.	$\frac{1}{d^2}$ = c.	Corrected Photometer Readings. 1	2	3	Mean R.
	Feet.		Per cents.	Per cents.	Per cents.	
1	8.438	0.0140	72.6	66.5	65.6	68.23
2	6.667	0.0225	59.1	33.6	37.5	43.40
[3	4.418	0.0505	27.7	....	....	27.7]

V. REDUCTION OF THE OBSERVATIONS.

From the observations made at the eclipse it is desirable to determine two things, namely: (a) the total light of the Corona = C; (b) the total light of the sky during totality = S. By "Corona" we understand everything around the Sun or Moon that is intrinsically brighter than the sky, which last we assume to be uniformly bright. No precautions were taken at the eclipse to protect the diffusing plates against the light from the sky. If we could suppose the amount of sky light that fell on each plate to be the same (and this can be effected by proper arrangements) we could without difficulty determine C and S from observations made at two different distances of the candle from the plate B. In the observations made at the eclipse the combined light of the Corona and a certain portion of the sky was compared with the combined light of the candle at a certain distance and another certain portion of the sky. Now let

c_0=total light on plate B, due to the candle at unit distance,=1.

c=total light on plate B, due to the candle at a distance $d, = \frac{1}{d^2}$

So=total light of *each* plate, due to the illumination from the sky (supposing the same amount fell upon each plate).

R=photometer reading for the distance d of the candle.

Then for observations made at the distances d_1 and d_2 we have the following equations:

$$\frac{So + C}{So + c_{I}} = \frac{R_{I}}{100} (1) \quad \frac{So + C}{So + c_{II}} = \frac{R_{II}}{100} (2) \quad So = \frac{R_{I}\, c_{I} - R_{II}\, c_{II}}{R_{II} - R_{I}} (3)$$

$$C = \frac{R_{I}}{100}(So + c_{I}) - So = \frac{R_{II}}{100}(So + c_{II}) - So \ (4)$$

Having So, and knowing what areas of the sky illuminated each plate, we can easily find S=total light of the sky according to any assumed law of distribution. The formulæ (1) to (4) just given hold good only when the total brightness of each plate due to the light of the sky is the same. Owing to many circumstances this was not the case at the eclipse. The eclipse station was in a valley, between mountains. The plate A, on which the light of the Corona fell, was turned upwards towards the Sun, and but little light was cut off from it by the mountains. The plate B stood vertically to the horizon, almost parallel to the crest of the mountain range, the apparatus being set up on the slope, and the plate turning its diffusing surface to the mountain. Hence only a portion of skylight could strike it. The screens, on the other hand, affected the plate A more than the plate B. Therefore, as far as the areas of the sky that threw their light on the plates is concerned, there may not have been so much difference. Indeed, measurements that have been made to determine these areas show that the area of sky on the plate A is to that on plate B as 40 to 39. However, from the plate B those portions of the sky were cut off that shone perpendicularly on it, while from A only portions near the horizon were cut off which would shine at a very large angle of incidence on the plate. From this it appears that in our case we cannot use the same value of So in the denominators and numerators of equations (1) and (2). We may, however, denote the total light of the plate B due to the illumination from the sky by x.So [So being, as stated above, the total light of A due to the sky light].

The equations now become:

$$\frac{So+C}{x.So+c_{I}} = \frac{R_{I}}{100} \ (5) \qquad \frac{So+C}{x.So+c_{II}} = \frac{R_{II}}{100} \ (6)$$

We have here three unknowns in two equations. From the equations it will be seen at once that we can determine two quantities, namely: So+C and x.So. Hence, without knowing x, we cannot separate C and So. The introduction of a third equation will

not lead to the determination of x, as really the unknowns in the equations are So+C and x.So. Hence we must find x from other sources. From the considerations given above it appears that x is a constant of the apparatus at the station, being due chiefly to the arrangement and situation of the apparatus, as the screens in this case, the surrounding hills, etc. This constant was not determined at the eclipse. However, it could be exactly determined at any time by setting up the same apparatus in all its details at the same place, and making observations on the relative brightness of the two plates (with or without employing a candle) at night, when we can assume the distribution of light in the sky to be uniform. An approximate value of x can be determined by measuring at any other place that part of the extinction of sky light which is due to the screens and to the relative position of the parts of the apparatus, eliminating hereby the effects due to topographical causes by proper arrangements. Another way would be to measure out the angular height and width of the different parts of the apparatus, as far as they could affect the plates, and to compute from these what portions of the sky were cut off from each plate. The part due to the topographical position of the eclipse station could be found approximately from the height of the surrounding mountains. Having thus found an approximate value of x, we can separate C and So, and determine both the "Brightness of the Coronal Ring" and the "Total Brightness of the Sky," and from these two the "Total Light at Totality" in terms of any unit we may choose.

Substituting in equations (5) and (6) the values for R and c given for set (1) and (2) in table III, we have:

$$So+C=0.6823\ So.x+0.6823\times 0.0140$$
$$So+C=0.4340\ So.x+0.4340\times 0.0225$$

from which $x.So=0.0009$ units (7)

$$So+C=0.0102 \text{ units } (8)$$

If we substitute these values of So.x and So+C in one of the equations (5) or (6) together with c from the third set we shall find

$R_{III}=20.0$. The observed value was $R_{III}=28.0$.

If we had taken the last observation into account we should have obtained

$$x.So=0.0108 \text{ units } (9)$$
$$So+C=0.0161 \text{ units } (10)$$

The maximum value x can attain in (7) is 1, in which case the amount of skylight on each plate would have been the same. In this case, So=0.0009 units, C=0.0093 units. The maximum value So can attain is 0.0102, when C=0; and $x=\frac{0.0009}{0.0102}=0.09$.

Taking these results together we have for the maximum and minimum values of x, 1.00 and 0.09.

For x=1.00	So=0.0009	C=0.0093
For x=0.09	So=0.0102	C=0.0000

Including the last observation the maximum and minimum values of x are 1.00 and 0.67.

For x=1.00	So=0.0108	C=0.0053
For x=0.67	So=0.0161	C=0.0000

The coronal light (C) must therefore have been less than 0.0093 units according to my observations at the eclipse. The calculation of the amount of sky light that illuminated the plate A, (So) will be given hereafter. I may state here that according to my estimation So was not less than $\frac{1}{3}$ S. Taking the maximum value of So=0.0161 we may infer that the total light of the sky must have been less than $3\times 0.0161=0.0484$, in which case the coronal light C is to be neglected with reference to that of the sky and therefore the total light at totality equals the total light of the sky. It afterwards will be seen that 0.0484 has to be multiplied by cos 45° in order to reduce to the same unit in which the coronal light is expressed. Hence according to my observations the total light at totality must have been less than 0.0342 units. At the same time So+C and So.x, on which the final results are based can by no means have been less than the quantities given in (7) and (8). The values of So+C and So.x depend on the distance of the candle. The larger d, the smaller these quantities will be. But it was impossible to obtain comparisons with the candle at a distance of about 10.5 feet. Even at 9.5 feet no comparisons could be made and it was only at a distance of 8.4 feet that I first succeeded in comparing the brightness of the plates. 8.4 feet being almost the limiting distance of the candle it appears that So+C and So.x cannot possibly have been less than 0.0102 and 0.0009.

I have endeavored to determine the constant x in two independent ways:

(*a*) By measurements of the different parts of the apparatus and by calculating their effect upon the plates A or B.

(*b*) By observations on the brightness of the night sky, so as to determine x directly.

Before giving these determinations it may be well to add here something about the illumination of an element of the horizon by the sky or any part of it. It is evident that the illumination of an element of the horizon due to portions of the sky near the horizon is less than that due to an equal portion of sky in the zenith under ordinary circumstances. The illumination depends not only on the zenith distance of the element of sky, but also on the substance of the element of the horizon. The law according to which the illumination of any substance falls off for portions of the sky, from the zenith to the horizon, has not been altogether fixed as yet. ZOELLNER (*Photometrische Untersuchungen*, Leipzig, 1865), SEELIGER (*Zur Photometrie Zerstreut Reflectirender Substanzen*, Muenchen, 1888), and others have shown, that LAMBERT'S cosine-law is only an approximation to the reality. Paper (white paper cardboard was used at the eclipse) is one of the substances that follows the law most closely. Based on the cosine-law, Dr. AUGUST BEER (*Grundriss des Photometrischen Calcules*, Braunschweig, 1854) has deduced formulæ, which will give for any intrinsic brilliancy of the sky=J the illumination of an element of the horizon due to any portion of the sky. In our case we are to determine the amount of sky light on each of the plates *B* and *A*, in order to find their ratio, which is x.

For the determination of the constant x the following measurements were made:

The plate A was shaded during the eclipse observations by screens whose angular dimensions were: mean altitude, 32°; width, 75°.

The plate B was shaded by screens whose angular dimensions were: mean altitude, 34°; width, 21°; and also by the dark box whose dimensions were: mean altitude, 13°; width, 80°.

The widths and altitudes of course were measured from the centre of the plate in each case. Light was cut off from both plates by the ring of mountains also. One of the photographs taken by Mr. BARNARD shows that the center of the Moon was 27.6 diameters above the crest of the mountains at totality. The altitude of the center of the Sun (or Moon) for the middle of totality was computed by means of an approximate longitude =122° 45′ and latitude=39° 17′ and found equal to 24° 6′. Subtracting from this the number of diameters of the Moon given

above (diam. of Moon=32′) we obtain for the altitude of the mountains at this point 9°.4. This then was assumed as the mean altitude of the mountains. These therefore cut off from the plate B, which stood vertically to the horizon, a zone the distance between the bases of which was sin 9°.4, the radius of the celestial sphere being taken as 1, and the width of which was 180°—101°=79°, 101° being the sum of the widths of the screen and the dark box.

It will be noticed that all the portions of the sky cut off from the plate B lay near the horizon of the station or, what is the same thing, near the zenith of the plate itself. To find the portions of the sky that illuminated the plate A it is necessary to know the inclination of the plate to the horizon=M. The plate is inclined to its axis at an angle of 45°, hence in rotating around its axis it describes a right cone with an angle of 90°=2N at the apex. If the plate stands vertically to the horizon, the normal plane, in which the incident ray, the normal and the reflected ray of an object near the horizon would lie, will be parallel to the horizon, or the angle between the two is zero. Taking this as the initial position of the normal plane, the angles between the same and the horizon will be reckoned downwards from right to left, *id est* in the direction in which the hands of a watch move. It is evident that to examine any object in the sky the normal plane has to be turned through an angle O=the altitude of the object. By aid of the angles N and O we find from simple geómetrical considerations the angle M=inclinations of plate A to the horizon=$\cos^{-1}$ (sin O cos N) or cos M=sin O cos N. In our case N=45°, O=24° 6′, hence M=73° 13′. This angle being reckoned downwards from the horizon, it appears, that the plate faced a lune of the sky of an angle=106° 47′. This and the date given above would determine the total area of sky on the plate A. Most of this was near the horizon of the plate. The ratio of the total areas of sky on the plates B and A=$\frac{39}{40}$ cannot be considered an approximate value of x, as their position in the sky with respect to the two zenith of the plates is so different that the illumination, due to equal portions of the sky, cannot be considered the same on both plates.

In order to arrive at a more correct value of x, the part of the sky illuminating the plate A was divided into a certain number of rectangular spherical triangles, one vertex always being at the zenith of the plate and the right angle at any one of the other

two. The same was done in the case of the plate B. According to BEER the illumination of an element of the horizon (the plane of the plate being here the horizon in each case) due to a triangle of the described character $=Q=\frac{1}{2}$ J. df'. v'. sin z', in which J = intrinsic brilliancy of a uniformly illuminated sky; v' = the side opposite to the angle at the zenith; z' = the shortest zenith distance of that side. The illumination of any one of the two plates is therefore equal to the algebraïc sum of the illuminations due to the triangles, the algebraic sum of which make up the portions of the sky that shone on the plate. For the plate A we have

$$Q'=\frac{1}{2}\ J.\ df'\times 164^\circ \quad (11), \text{ and for B}$$

$$Q''=\frac{1}{2}\ J.\ df'\times 94^\circ \quad (12)$$

The illumination of the plates due to reflection from the ground has been neglected in both cases.

Hence $x=\frac{Q''}{Q'}=0.57$

Substituting this value of x in equations (7) and (8) we have

$$So=0.0016 \quad (13)$$

$$C=0.0086 \quad (14)$$

According to this value of x the total visual brightness of the Corona was 0.0086 units. BEER gives for the illumination of an element of the horizon due to a whole hemisphere = sky, Q = J. df'. π. The illumination due to the combined portions of sky on each plate is $Q'+Q''=$J. df'. 129°. Hence the total visual brightness of the sky is to the combined brightness (So + x.So) of the two plates as $\frac{180}{129}$ or the total visual brightness of the sky $=S=\frac{180}{129}0.0025=0.0035$.

It must be remembered that the number 0.0035 expresses what would have been the brightness of the plate A due to a whole hemisphere (sky) in terms of the candle shining at an angle of 45° (on the plate B), while the coronal light has been expressed in terms of the same candle shining perpendicularly (on the plate B), the effects due to the inclination being eliminated in this case. Hence in order to reduce the total light of the sky to the same unit in which the coronal light has been expressed, we must multiply 0.0035 by cos 45° and obtain S=0.0025. The total visual light at totality, being equal to the sum of the total visual light of the Corona and that of the sky=S+C was therefore 0.0111 units.

The value of x which led to the results just given was calculated on the hypothesis that the height of the mountains was uniform all around. In fact the altitude of the mountains faced by the plate B was much larger than that of the mountains faced by the plate A. Therefore, according to BEER's formulas, x cannot have been larger than 0.57, and we may now draw our limits somewhat more closely by assuming this as a maximum value of x. The altitude of the mountains faced by the plate B was probably not more than twice the altitude of those faced by A. We may therefore arrive at a minimum value of x by computing Q_{I} and Q_{II} on the hypothesis that the altitude of the mountains that affected the plate B was twice the altitude of those that affected A. In this case

$$Q_{I}=\tfrac{1}{2}\,J.\,df'.164^{\circ}\ (11a) \qquad Q_{II}=\tfrac{1}{2}\,J.\,df.65^{\circ}\ (12a)$$

$$x=\frac{Q_{II}}{Q_{I}}=0.40.$$

According to this value of x

$$C=0.0079 \text{ units; and } S=0.0036 \text{ units } (13a)$$

$$S+C=0.0115 \text{ units } (14a).$$

It is worth noticing that the total visual light at totality is almost the same for both limits of x, being equal to 0.0111 and 0.0115 units.

I have also endeavored to determine the constant x directly by means of observations on the relative brightness of the two plates, due to the night sky before the rising or after the setting of the Moon. In order to have a perfectly clear horizon the photometer-apparatus was set up in all its details (including the screens), as it was used at the eclipse on top of one of the reservoirs (KEPLER) of the Observatory, which lies about 40 feet higher than the Observatory itself. In some observations screens were employed to produce the same effect as the mountains at the eclipse, so that the constant x, as obtained with a clear horizon, should need no further correction. The last observations were made, while the Milky Way was above the horizon. As its effect on the two plates from its position in the sky could be assumed to be the same, no corrections for it were applied. The results obtained are not at all satisfactory, chiefly because the accidental variations of the comparison-light (various kinds of light have been tried) were larger than the quantities measured.

The values of x as obtained on different nights are not given here, as they cannot be of any value. They vary from $x = +4.9$ to $x = -0.3$, in two cases x even being equal to -16.7 and -72.2.

Thus being convinced by many trials that it was impossible to determine x by the aid of a comparison-light, I abandoned the attempt and placed the wheel-photometer on the other side of the dark box between the box and the brighter plate A. The photometer readings divided by 100 now expressed directly the ratio of the amount of sky light on the two plates = x. The mean value of x found in this fashion from 75 comparisons in three nights is $+0.56$, this value being almost identical with the one obtained by BEER's method on the hypothesis of uniform mountains and also giving the same final results. I therefore adopt 0.56 as the most probable value of x, obtainable under the circumstances. Thus a definite value of x being decided upon the observations made at the eclipse give the following results:

Maximum possible total light at totality = 0.0342 units.

Most probable total visual brightness of the sky = 0.0025 units.

Most probable total visual brightness of the Corona = 0.0086 units.

Most probable total light at totality = 0.0111 units.

It may be of interest to know what these results would presuppose to be the intrinsic brilliancy of the sky (J) and of the Corona (J'). Equation (12) gives for the illumination of the plate B

$$Q_{II} = \tfrac{1}{2} J \, df' . \tfrac{9.4}{57.296};$$

Or, taking 1 square minute as the unit of area,

$$Q_{II} = J \, 1 \square' \tfrac{4.7}{57.296}.$$

If the theory is correct, this must correspond to the observed brightness of the plate, which is $0.0009 \times \cos 45^{\circ} = 0.00064$ units.

Hence $$\tfrac{4.7}{57.296} \times J \times 1 \square' = 0.00064 \quad (15)$$

$$J \times 1 \square' = 0.00078 \text{ units.}$$

Or, according to my observations at the eclipse, the intrinsic brilliancy of the sky was 0.00078 units.

In the case of the Corona we must assume this to have the shape of a ring, concentric with the Sun or Moon, and of the same area as the Corona. If we denote by J' the mean intrinsic brilliancy of this ring, by z the zenith distance of its centre, and by $\left\{ \begin{matrix} r_o \\ r_i \end{matrix} \right\}$ its $\left\{ \begin{matrix} \text{outer} \\ \text{inner} \end{matrix} \right\}$ angular diameter, the theory gives

$$Q = \tfrac{1}{2} J' \, df. \cos z \, (\cos 2r_i - \cos 2r_o) \, \pi \quad (16)$$

For the illumination of an element of the horizon due to the ring.

In our case $2r_i=33'.3$, $2r_o=58'.2$ $z=45°$=angle of incidence of Corona on plate A. The observed brightness of the plate A due to the Corona was 0.0086 units. Hence if the theory is true we must have

$$\tfrac{1}{2}J'\,1\,\square'\cos 45°\,(\cos 33'.3-\cos 58'.2)\,\pi=0.0086 \quad (17)$$

$(\cos 33'.3-\cos 58'.2)$ is very nearly=zero.

Hence the value of J' obtained from (17) will be extremely uncertain. I therefore reject the value of $J'\times 1\,\square'=76.5$, and have simply stated the result of the computation for completeness.

While it is evident that the intrinsic brilliancy of the Corona should be much greater than that of the sky, yet *a priori* we should expect the total visual brightness of the sky to be greater than that of the Corona. In fact, Prof. HOLDEN's photometric measurements on the photographic plates show that the sky was 3,000 times as bright as the Corona. Prof. HOLDEN has determined the areas of the equally bright portions of the Corona, which he arbitrarily divides into five portions. Beginning from the middle, the intrinsic brilliancies of the equally bright portions are in the ratios 12:8:4:2:1, 1 being the intrinsic brilliancy of the sky. The following interesting experiment may be made with these data. *A priori* we can assume that the ratio of the total visual brightness of a unit of area of the different portions of the Corona and of the sky is the same as the ratio of their intrinsic photographic brilliancies. If we denote by J the intrinsic brilliancy of the sky, we have for the intrinsic brilliancy of the different portions of the Corona 12 J, 8 J, 4 J, 2 J, J. If we suppose the equally bright portions of the Corona to be strictly concentric with the Moon, we can from the areas compute the inner and outer diameters of these rings of equal brightness. Substituting these diameters and the different intrinsic brilliancies, together with the quantities referring to the sky, for the plate A, in BEER's formulas, we obtain an equation for determining J. The corresponding quantities for the plate B furnish another equation. Thus having determined J, we can from BEER's formulas find the

Total visual light of the Corona.
Total visual light of the sky.
Total visual light at totality.

If we do not include the last observation of Table II, no result can be obtained in this manner. Including the last observation, we find for J

From the equation for plate A, J = 0.0093 units.
From the equation for plate B, J = 0.0079 units.
The mean being J = 0.0086 units.

And from this we find:

Total visual brightness of sky = 0.027 units.
Total visual brightness of Corona = 0.00005 units.
Total visual light at totality = 0.027 units.

As the total visual brightness of the Corona in this case is very small as compared with that of the sky, x here attains its minimum value = 0.67 (comp. max. and min. values of x for (9) and (10)).

VI. Results of the Observations.

Owing to many circumstances, this report has become more extensive than it originally was intended to be. I therefore give here a brief synopsis of what we may regard as the results of my photometric work at the eclipse.

Maximum possible total light at totality = 0.0342 units.
Most probable total visual brightness of the sky = 0.0025 units.
Most probable total visual brightness of the Corona = 0.0086 units.
Most probable total visual light at totality = 0.0111 units.
Most probable intrinsic brilliancy of the sky = 0.00078 units.

The unit of this table is a wax candle shining through a piece of glass, at a distance of one foot.

While this report was in print, I compared the brightness of the eclipse candle with that of the Standard lamp of the Lick Observatory. The definition of a visual light-unit of the Standard lamp is similar to the definition of a photographic light-unit, the visual unit being the amount of light emitted by the lamp through a circular aperture, one mm. in radius, at a distance of one meter. Accordingly the Standard lamp was placed at a distance of one meter from the plate *A*. Precautions were taken that no other light than the light of the lamp and the candle illuminated the plates *A* and *B* respectively. The Lick Observatory does not possess for the Standard lamp a diaphragm with an aperture exactly one mm. in radius, but there are two others with apertures, 1.015 and 3.18 mm. in radius respectively. Both these apertures were used in the comparisons. From 110 comparisons, taken in four nights with the candle at different distances, a candle-unit was found to represent 125±2 lamp-units. Expressing the final results in visual lamp-units we obtain:

Maximum possible total light at totality=4.28 units.
Most probable total visual brightness of the sky=0.31 units.
Most probable total visual brightness of the Corona=1.08 units.
Most probable total visual light at totality=1.39 units.
Most probable intrinsic brilliancy of the sky=0.098 units.

VII. Suggested Improvements in the Apparatus.

It will have been noticed, where the advantages and disadvantages of our apparatus lie. The chief advantage of the principle employed is, that it allows us to separate the light of the Corona from the light of the sky. The disadvantages presented by the apparatus in the form in which it was used at the eclipse, are very serious. They can be overcome, however, by very small changes in the disposition of the photometer. The determination of the constant x was attended with great difficulties, and the value given for it is not as certain as desirable. Besides, the light of the Corona and of the sky was not measured directly in terms of a candle, but in terms of the combined light of a candle and a certain portion of the sky: the latter was to be determined from the observations. All this can be avoided by suitable changes in the apparatus without rendering it difficult to separate the light of the object (Corona, Moon, etc.,) from the light of the sky. I therefore suggest the following improvements on the photometric arrangements assigned to me at the eclipse:

The constant x should be reduced to zero, or at least have a certain known value, as for example unity. But it is not easy to arrange the different parts of the apparatus so that the ratio of the amount of the light on the two plates equals unity or any other given number, for even if the ratio of the areas of sky that illuminate the plates had that value, the position of the areas in the sky could not be made the same with respect to the plates. The reduction of x to zero on the other hand is easily effected in the apparatus and makes the subsequent computations extremely simple. All that is necessary is to have the plate B, the candle, the board, the photometer, in short, all parts connected with the plate B in complete darkness. This can be done in several ways, according to the convenience of the observer. It will at once be seen that this arrangement also enables us to measure the light of the plate A directly in terms of the candle.

In order to separate the light of the object (Corona) from that of the sky, we can limit the area of sky, from which light reaches

the plate (A), by means of tubes with diaphragms. By measuring then the brightness of the plate, 1st, with the Corona included in this area; and 2d, with the Corona excluded and with sky illumination only, we can determine the brightness of each object separately. The area of sky on the plate is determined by the solid angle subtended by the aperture of the diaphragm at the centre of the plate. The centre of the plate will be somewhat brighter than the other parts; this, however, will hardly affect the final results, if the apertures in the box are chosen so that only the middle portions of A throw their light on the mirror a. In order to have the angle of incidence on the plate=45°, the axis of the solid angle must be inclined to the plate at an angle of 45°. In our apparatus we could attach the plate A to a little box as a base, so that it makes an angle of 45° with the axis of the box, the diaphragm being at the top. An aperture in this box of the same size as the hole in the dark box will allow the light of the plate to fall on the mirror a. In revolving the plate around its axis, the axis of the box describes a plane, into which the object is to be brought, this plane corresponding and being parallel to the plane of the righthand side of the dark box, mentioned in the early part of this report. To determine the brightness of the Corona at an eclipse the apparatus is to be adjusted as described. We then measure first the brightness of the plate A due to the combined light of the Corona and the known portion of the sky, after which the Corona is thrown out of the field by slightly revolving the plate A around its axis, and the brightness of an equal portion of sky without the Corona is measured.

From both sets we can then deduce the

Total visual light of the Corona=C.
Total visual light of the sky=S.
Total visual light at totality=S+C.

Other arrangements of the apparatus will lead to the same results; the one given, however, seems to me to be the best, as requiring the least amount of time for the actual observations.

It was intended to determine with this apparatus:

1. The visual brightness of the Moon in terms of the candle.

2. The visual brightness of the Moon in terms of a Standard lamp.

3. The visual brightness of the candle in terms of a Standard lamp.

But there being no chimneys for the Standard lamp obtainable here, and those ordered from the East some months ago having arrived too late, parts 1 and 2 of this programme had to be postponed. The subject will, however, be resumed here in the near future, either by myself or by another observer.

Respectfully submitted,

ARMIN O. LEUSCHNER.

TO MR. J. E. KEELER, Lick Observatory.

REPORT ON THE GEOGRAPHICAL POSITION OF NORMAN, CALIFORNIA.

By JAMES E. KEELER.

Among the points at which observations were made during the total solar eclipse of January 1, 1889, is Norman, a little town on the northern branch of the Southern Pacific Railroad, in Colusa County, California. Its position, taken from a map of the State, is approximately,

$$\varphi = 39^\circ\ 25'$$
$$\lambda = 8^h\ 8^m\ 48^s \text{ from Greenwich.}$$

This station, which was very nearly in the central line of the eclipse, was occupied by a party in charge of Professor H. S. PRICHETT, of Washington University, St. Louis, and a more accurate knowledge of its geographical position than could be obtained from maps was necessary for the reduction of the observations which were made there.

As Professor PRITCHETT remained in the State but a short time, during which the weather was very unfavorable, he applied to the Lick Observatory for the requisite information, and in February I was authorized by the Director to proceed to Norman and make such observations as would give the latitude and longitude of the place with a sufficient degree of accuracy, and with small expenditure of time and money.

The instruments used were, the portable altazimuth or universal instrument by A. REPSOLD & SONS, briefly described in Vol. I, *Publications of the Lick Observatory*, sidereal chronometer NEGUS 1720, and an aneroid barometer and a thermometer for determining the refraction. The altazimuth is a handsome instrument of elaborate construction and high finish. It packs in two hard wood cases, and these in rough padded packing-boxes for transportation. The observations included a complete investigation of all its constants, most of which had never been determined.

I arrived at Norman on February 14, and looked for a place to set up the instrument. No suitable place could be found, and the difficulty proved to be quite a serious one. There were no bricks and mortar to be had in Norman, which consists of but a few

scattered houses and the railway station, and none in the neighboring towns. The delay and expense of procuring them at a distance would have been too great, and I was finally obliged to use the chimney of a furnace which stood in the farmyard not far from the point where the eclipse observations were made, as the only support at all fitted for the purposes of a pier. The furnace was used for preparing feed for the live stock on the ranch of Mr. N. D. Rideout. It was low, built of brick, plastered with mud, and the chimney (which was about 3 feet high) was lamentably unsteady, so that the greatest care had to be taken not to press upon it during the course of the observations. A rude scaffolding which I constructed over the furnace enabled me to make the observations with circle west without disturbing the pier, but in this position of the instrument observation was attended with much personal discomfort. I mention these facts because the results of the work, although of amply sufficient accuracy, do not quite represent the capacity of the instrument when used under the most favorable conditions on a suitable support. In measuring zenith distances with the vertical circle, the instability of the pier was not of much consequence, as the level attached to the microscopes could be read immediately after making a bisection of a star, but for the time observations with the instrument in the plane of the meridian, the imperfect nature of the support was probably the greatest source of inaccuracy.

The observations of Mr. Pritchett were made in front of the house on the ranch of Mr. Rideout. The proprietor was absent at the time of my visit, but by the courtesy of Mr. Mason, his agent, who left Norman on the day of my arrival, I was invited to stay at the house during the course of my work, and the servant who was left in charge provided for all my wants.

The house was between half and three quarters of a mile north of the telegraph station, by the side of the railroad track. Every evening at eight o'clock I carried the chronometer to the station and compared it with signals from the mean time clock on Mt. Hamilton, returning immediately afterward to the instrument for a determination of the local time. On account of clouds in the early evening, the chronometer correction was determined before the telegraphic signals on but one occasion.

Through the kindness of Mr. F. L. Van Denburgh, Superintendent of Telegraphs of the Southern Pacific Company, I was given the use of a direct wire to San José, free of expense, on the nights of February 15, 16, 17, 18, and 19. Cloudy weather pre-

vented observation on the nights of February 15 and 17, leaving three nights' comparisons for the determination of the longitude. The chronometer was also compared every day with the signals which are regularly sent out from the Observatory at noon, but as these signals are repeated on the Northern Division at Sacramento by hand, they have been used merely as a check on the more accurate evening comparisons. In all the telegraphic work I had the intelligent assistance of Mr. M. B. Wiley, the operator at Norman.

The instrument was not dismounted after the evening observations, but was merely covered with a tarpaulin, to protect it from damp. On the early morning of February 17 it was overthrown by a horse, who broke into the enclosure at night, and pushed it off the pier with his nose, fortunately without doing it any damage whatever.

Description of the Instruments.

The *Altazimuth* used in these observations has a horizontal circle 10 inches in diameter, and a vertical circle 9½ inches in diameter, both divided on silver to 4′, and read by micrometer microscopes to 2″, or by estimation to 0″.2. The horizontal circle was used only as a check on the azimuth, or for setting the instrument approximately in the meridian.*

The telescope has an aperture of 2.15 inches and a focal length of 19.75 inches. The tube is "broken" in the middle, where a reflecting prism sends the rays out through the axis to the eye. A spring counterpoise roller under the middle of the axis supports nearly the whole weight of the telescope, axis, and circle, so that the flexure peculiar to this form of instrument is almost entirely avoided. The pivots are of steel, 1.25 inches in diameter, and the bearing surfaces of the Y's are 11½ inches apart.

The reading microscope on the left of the eyepiece is called C, that on the right D. Two revolutions of either screw measure one division, or 4′ of the circle, and the heads are divided into 60 parts, so that 1 division = 2″. Two determinations during the course of the work showed no appreciable error of runs.

When the telescope is vertical, microscope C reads 0°, and microscope D 180°. The figures on the circle increase in the opposite direction from those on the face of a watch. The degrees and minutes of the circle reading were taken from microscope D.

* The horizontal circle of this instrument has one or two very bad division errors. Thus, the space on the left of 0° is too great by 7″.8, that on the right too small by 10″.7. No large errors have been found in the vertical circle.

The level on the microscope alidade is figured from 0 to 50, increasing from C toward D. The division 30 is nearly in the middle, and all circle readings have been reduced to this position of the bubble. 1 division of the level is equal to 1".15. An increase in the level reading increases the circle reading; hence if D is the circle reading given by the microscopes, and L the reading of the middle of the bubble, the corrected circle reading is

$$D + 1''.15\ (30 - L.)$$

The reticle contains nine vertical threads (vertical when the telescope is directed to the horizon), and two horizontal ones about 30" apart. Three of the vertical threads form a close central group, and were used in observiug slow moving stars. The horizontal thread nearest to the micrometer screw, which is on one side of the box, was used in observing zenith distances. One revolution of the micrometer head=$5^s.950$, and one division=$0^s.0595$.

There are two eyepieces, one magnifying 36 and the other 80 diameters. The high power was used in all observations except those of February 16.

A table of equatorial intervals is given below. A star observed at upper culmination, circle west, crosses the field in the order of the threads.

Wide Threads.			Central Group.		
Thread.	From Mid. Thread.	From Mean Th.	Thread.	From Mid. Thread.	From Mean Th.
I	$+36^s.582$	$+36^s.481$			
II	+25 .089	+24 .988	IVa.	$+1^s.878$	$+1^s.777$
III	+13 .355	+13 .254	IV	0 .000	−0 .101
IV	0 .000	−0 .101	IVb.	−1 .988	−2 .089
V	−13 .384	−13 .485			
VI	−24 .667	−24 .768			
VII	−36 .270	−36 .371			

$\Delta i = +0^s.101$.

The striding level for the axis has a scale numbered consecutively from one end to the other. One division=$1''.32=0^s.088$. On returning to the Observatory this level was investigated with the level-trier, and a very bad place discovered near the lower end of the scale; hence some level readings made in the field have been rejected. The correction for inequality of pivots is $0^s.04$, additive with circle east; or, using the notation of CHAUVENET,

Circle west, $b = B - 0^s.04$.
Circle east, $b' = B' + 0^s.04$.

The instrument is provided with apparatus for reversing the axis, the striding level remaining in position during the operation.

The *Chronometer*, NEGUS 1720, is regulated to sidereal time, and when taken from the Observatory, at noon, February 12, was 1^m $53^s.3$ slow of local time, with a losing daily rate of $1^s.2$.

The *Aneroid Barometer* is one of the larger class of these instruments, and is reliable. The index correction (to the mercury barometer at 32°) is $+0^{in}.12$, sensibly constant for all temperatures.

The *Thermometer* is an ordinary mercury thermometer without sensible error.

OBSERVATIONS.

a. Time Observations.

For the determination of the chronometer correction the alt-azimuth was placed in the plane of the meridian and used as a transit instrument, the transits of stars over the seven right ascension wires being observed by the eye and ear method. The microscopes of the horizontal circle were frequently examined during the course of the observations to detect any change of azimuth, particularly when the axis was reversed, but no certain change was ever noticed. Any change due to instability of the pier could not, of course, be detected in this way.

February 16, 1889.

The chronometer had been set on leaving the Lick Observatory so that it should be about 14^s fast of Norman sidereal time. The meridional point of the azimuth circle had been roughly determined by an observation of the Sun in the forenoon.

At 4^h 57^m 20^s, the R. A. of ε Urs. Min. S. P., the middle thread was placed upon that star. Then the transit of μ Aurigae, near the zenith, (1° 4′ S.) was observed, as follows:

μ Aurigae (7 wires) 5^h 6^m $4^s.51$
$\alpha=$ 5 5 49 .8
Approx $\Delta T=$ $-14^s.7$

After this the chronometer was taken to the telegraph station and compared with the Lick Observatory clock signals.

On returning from the station, time observations were continued.

R. A. δ Draconis, S. P.$=7^h$ 12^m $29^s.2$
Chronometer $\Delta T=$ -14 .7
Chronometer time of transit$=7$ 12 43 .9

The middle thread was set upon the star at this time. The reading of azimuth circle =198° 38′ 50″.0.

Transits of stars were then observed as follows:

CIRCLE EAST.

β Geminorum	(7 wires)	$7^h\ 22^m\ 13^s.67$	$b' = -0^s.75$
α^2 Geminorum	(7 wires)	7 27 46 .29	$b' = -0.80$
24 Lyncis	(7 wires)	7 34 52 .76	$b' = -0.80$
ι Draconis, S. P.	(7 wires)	7 48 43 .90	$b' = -0.80$
χ Geminorum	(7 wires)	7 56 57 .37	$b' = -0.80$

CIRCLE WEST.

κ Cephei, S. P.	(7 wires)	$8^h\ 12^m\ 46^s.21$	$b = -0^s.40$
30 Monocerotis	(7 wires)	8 20 22 .03	$b = -0.48$
γ Cancri	(7 wires)	8 37 6 .94	$b = -0.54$
ι Cancri	(7 wires)	8 40 13 .93	$b = -0.60$

LEVEL READINGS.

$7^h\ 18^m$	$7^h\ 34^m$	$7^h\ 42^m$
W. 27.5 E. 54.8 35.4 7.8	W. 32.0 E. 5.0 26.0 53.5	W. 30.0 E. 57.5 28.0 0.0
$8^h\ 1^m$	$8^h\ 24^m$	$8^h\ 30^m$
W. 40.0 E. 12.5	W. 32.0 E. 60.0 52.4 24.8	W. 25.1 E. 53.0 42.5 14.4

NOTE: Some of these readings, for reasons already given, have been rejected. The level correction used for each star in the reductions is given after the time of transit.

Reduction of these observations gives the following results:

β Geminorum	$\Delta T = -13^s.93$	Epoch $= 8^h\ 0^m$
α^2 Geminorum	$-13 .65$	Assumed δ T $= +4^s$
24 Lyncis	$-13 .64$	$a = -0^s.37$
χ Geminorum	$-13 .82$	$c' = \begin{cases} -0^s.10 \text{ circle west.} \\ +0 .07 \text{ circle east.} \end{cases}$
30 Monocerotis	$-13 .88$	
γ Cancri	$-13 .83$	
ι Cancri	$-13 .65$	
	$\Delta T = -13^s.77 \pm 0^s.03$	

February 17, 1889.

Early in the morning the instrument was thrown over by a horse. The rest of the day was spent in readjusting it. The night was cloudy and only a broken transit of α Aurigae was observed, giving chronometer $\Delta T = -9^s$, azimuth uncertain. The meridional point of the azimuth circle is now about 321° 30′.

February 18, 1889.

The instrument was placed as nearly as possible in the meridian and the transit of δ Tauri observed, giving chronometer $\triangle T = -6^s.23$.

At $4^h\ 22^m\ 35^s$, the chronometer time of transit of η Draconis, S. P., set the middle thread on this star. The azimuth circle reading was then 321° 29′ 45″.8.

CIRCLE EAST.

α Tauri	[7 wires]	4^h	20^m	$39^s.11$		$b' = +0^s.09$
ι Aurigae	[7 wires]	4	49	51 .96		$b' = +0.09$
ε Aurigae	[7 wires]	4	54	6 .23		$b' = +0.09$
ε Leporis	[7 wires]	5	0	51 .83		$b' = +0.09$

CIRCLE WEST.

ζ Draconis, S. P.	[3]	5^h	8^m	$32^s.53$	$b = +0^s.02$
τ Orionis	[6]	5	12	19 .34	$b = +0.04$
β Tauri	[7]	5	19	22 .71	$b = +0.12$
χ Aurigae	[7]	5	25	36 .37	$b = +0.25$

LEVEL READINGS.

$4^h\ 34^m$	$4^h\ 45^m$	$5^h\ 4^m$	$5^h\ 15^m$	$5^h\ 29^m$
W. 23.2 E. 46.3	W. 46.5 E. 22.8	W. 21.8 E. 45.7	W. 18.7 E. 43.0	W. 50.8 E. 26.3
45.5 22.0	22.4 46.1	44.3 20.6	46.4 22.0	16.2 40.9

The results of the reduction of these observations are as follows:

α Tauris	$\triangle T = -6^s.50$	Epoch $= 5^h\ 0^m$
ι Aurigae	-6.44	Assumed $\delta T = +4^s$
ε Aurigae	-6.40	$a = +0^s.15$
ε Leporis	-6.40	$c' = \begin{cases} -0^s.10 \text{ circle west.} \\ +0.07 \text{ circle east.} \end{cases}$
τ Orionis	-6.49	
β Tauri	-6.39	
χ Aurigae	-6.35	
	$\triangle T = -6^s.42 \pm 0^s.02$	

The collimation constant was carefully determined by observation of a terrestrial mark.

The chronometer was then taken to the telegraph office for comparison with the Lick Observatory signals. On returning to the instrument, time observations were continued.

CIRCLE WEST.

ε Geminorum	[7 wires]	6^h	37^m	$22^s.19$	$b' = +0^s.17$
51 Cephei	[4 wires]	6	48	44 .49	$b' = +0.22$
ζ Geminorum	[7 wires]	6	57	47 .47	$b' = +0.26$
63 Aurigae	[7 wires]	7	4	17 .30	$b' = +0.28$

CIRCLE EAST.

α^2 Geminorum	[7 wires]	$7^h\ 27^m\ 46^s.17$		$b = +0^s.80$
25 Monocerotis	[7 wires]	7 32	1 .14	$b = +0\ .77$
β Geminorum	[7 wires]	7 38	46 .59	$b = +0\ .73$
ε Draconis, S. P.	[7 wires]	7 48	45 .53	$b = +0\ .63$
χ Geminorum	[7 wires]	7 56	57 .67	$b = +0\ .50$
27 Lyncis	[7 wires]	8 0	22 .29	$b = +0\ .46$
ζ' Caneri	[7 wires]	8 6	6 .41	$b = +0\ .35$

The immense flocks of wild geese continually flying over made such a noise that it was frequently difficult to hear the chronometer beats.

LEVEL READINGS.

$6^h\ 30^m$	$6^h\ 54^m$	$7^h\ 8^m$	$7^h\ 35^m$
W. 17.3 E. 43.3 48.8 22.2	W. 46.6 E. 28.3 20.2 38.4	W. 19.7 E. 38.0 47.3 29.1	W. 51.2 E. 33.4 18.5 36.3

$7^h\ 44^m$	$7^h\ 52^m$	$8^h\ 10^m$
W. 14.4 E. 39.7 53.1 27.6	W. 51.0 E. 25.6 15.0 40.5	W. 17.0 E. 42.6 46.7 21.0 47.3 21.7 17.5 43.0

Reduction of these observations gives the following results:

ε Geminorum	$\Delta T = -15^s.67$	Epoch $= 7^h\ 30^m$
ζ Geminorum	$-15\ .64$	Assumed $\delta T = +4^s$
63 Aurigae	$-15\ .71$	$a = +0^s.05$
α^2 Geminorum	$-15\ .58$	$c' = \begin{cases} -0^s.10 \text{ circle west.} \\ +0\ .07 \text{ circle east.} \end{cases}$
25 Monocerotis	$-15\ .79$	
β Geminorum	$-15\ .58$	
χ Geminorum	$-15\ .77$	
27 Lyncis	$-15\ .98$	
ζ' Caneri	$-15\ .59$	

$$\Delta T = -15^s.70 \pm 0^s.03$$

From these observations it is evident that either in going to or returning from the station, the seconds hand of the chronometer got forward several divisions, probably through some twist which increased the amplitude of the balance wheel, unlocked the detent, and allowed several teeth of the scape-wheel to pass. The road was very rough, and in the dark, with only the aid of a lantern, it was impossible to avoid giving the chronometer some rather rough shocks. On the way to the station I stumbled once over a large rock. A preliminary reduction the next day showed that some accident had occurred, and I therefore telegraphed a request

that the signals should be sent the next night. The results obtained on other evenings show that the jump in the chronometer correction occurred before the comparisons at the telegraph station, so that the observations of this night also are available for determining the longitude.

February 19, 1889.

The axis having been leveled and the azimuth circle set to the reading for the meridian, transits of α Tauri and ι Aurigae were observed, giving respectively the chronometer corrections $\triangle T = -11^s.91$ and $\triangle T = -11^s.98$. The middle thread was then placed upon ε Urs. Min. S. P. at Chr. $4^h\ 57^m\ 47^s$. The right ascension was taken from the observing list, and the star was therefore not exactly on the meridian at that time.

The reading of the azimuth circle was then 321° 28′ 59″.8.

CIRCLE EAST.

μ Aurigae	[7 wires]	$5^h\ 6^m\ 1^s.83$	$b' = -0^s.04$
α Aurigae	[6 wires]	5 8 40 .81	$b' = +0.09$

CIRCLE WEST.

β Tauri	[5 wires]	$5^h\ 19^m\ 29^s.03$	$b = -0^s.04$
χ Aurigae	[7 wires]	5 25 42 .79	$b = 0.00$
α Leporis	[7 wires]	5 28 4 .49	$b = +0.03$

LEVEL READINGS.

$4^h\ 34^m$		$5^h\ 2^m$		$5^h\ 11^m$		$5^h\ 17^m$		$5^h\ 30^m$	
W. 44.0	E. 22.0	W. 24.0	E. 46.0	W. 19.4	E. 42.0	W. 19.4	E. 42.0	W. 44.0	E. 20.5
23.5	45.4	40.1	17.9	43.6	20.7	43.6	20.7	17.3	40.6

The results of reductions are given below:

μ Aurigae	$\triangle T = -11^s.99$	Epoch = $5^h\ 30^m$
α Aurigae	-12.18	Assumed $\delta T = +4^s$
β Tauri	-11.85	$a = -2^s.75$
χ Aurigae	-12.06	$c' = \begin{cases} -0^s.10 \text{ circle west.} \\ +0.07 \text{ circle east.} \end{cases}$
α Leporis	-11.85	

$$\triangle T = -11^s.99 \pm 0^s.04$$

The chronometer was then taken to the station and compared with the Lick Observatory signals. On returning from the station time observations were continued.

CIRCLE WEST.

63 Aurigae	[7 wires]	7h	4m	13s.20	b = +0s.08
25 Camelop.	[2 wires]	7	7	42 .78	b = +0 .09
δ Geminorum	[7 wires]	7	13	42 .31	b = +0 .12
τ Draconis, S. P.	[6 wires]	7	17	57 .76	b = +0 .12
ρ Geminorum	[7 wires]	7	22	10 .56	b = +0 .12
α^2 Geminorum	[7 wires]	7	27	43 .21	b = +0 .12

CIRCLE EAST.

φ Geminorum	[7 wires]	7h	46m	54s.59	b′ = +0s.10
χ Geminorum	[7 wires]	7	56	54 .37	b′ = +0 .10
27 Lyncis	[7 wires]	8	0	17 .29	b′ = +0 .10
ζ' Cancri	[7 wires]	8	6	3 .51	b′ = +0 .10
$\varkappa'$ Cephei, S. P.	[7 wires]	8	12	55 .29	b′ = +0 .10
30 Monocerotis	[7 wires]	8	20	20 .56	b′ = +0 .10

LEVEL READINGS.

6h 57m		7h 11m		7h 31m		7h 38m	
W. 16.0	E. 40.5	W. 45.6	E. 20.9	W. 15.0	E. 39.8	W. 43.6	E. 18.9
44.8	19.6	15.0	39.8	46.1	21.5	18.4	43.0
				46.1	21.2		
				16.5	41.0		

7h 50m		8h 8m		8h 24m	
W. 17.1	E. 41.9	W. 43.8	E. 19.0	W. 20.0	E. 44.0
42.0	17.0	19.0	44.0	42.9	18.0
				42.0	17.0
				19.0	43.1

Reduction of these observations gives the following results:

63 Aurigae	ΔT = —11s.40	Epoch = 7h 30m
δ Geminorum	—11 .38	Assumed δ T = +4s
ρ Geminorum	—11 .41	a = —2s.80, circle west.
α^2 Geminorum	—11 .23	a = —2s.75, circle east.
φ Geminorum	—11 .37	c′ = { —0s.10, circle west. +0 .07, circle east.
χ Geminorum	—11 .38	
27 Lyncis	—11 .39	
ζ' Cancri	—11 .47	
30 Monocerotis	—11 .46	
	ΔT = —11s.39 ± 0s.02	

February 20, 1889.

Thin, hazy clouds, but excellent definition. No signals were sent from the Observatory, but the chronometer correction was approximately determined for rate, and for the latitude observations which were made later in the evening.

From a transit of ι Aurigae, ΔT = —8s.5. The middle thread was then set upon ε Urs. Min. S. P. at 4h 57m 29s. Reading of azimuth circle, 321° 29′ 38″.0.

Circle East.

μ Aurigae	[7 wires]	$5^h\ 5^m\ 57^s.91$	$b' = +0^s.07$
α Aurigae	[7 wires]	5 8 37 .33	$b'' = +0.12$

Circle West.

χ Aurigae	[7 wires]	$5^h\ 25^m\ 38^s.23$	$b = +0^s.06$
ζ Tauri	[7 wires]	5 31 8 .66	$b = +0.08$
ω Draconis, S. P.	[7 wires]	5 37 42 .29	$b = +0.12$

Level Readings.

$4^h\ 41^m$	$5^h\ 2^m$	$5^h\ 12^m$
W. 35.0 E. 12.2 13.5 36.0	W. 13.0 E. 36.0 34.8 11.2	W. 37.0 E. 14.0 12.5 35.6
$5^h\ 15^m$	$5^h\ 34^m$	$5^h\ 43^m$
W. 38.3 E. 15.0 11.5 34.6	W. 10.0 E. 34.0 38.6 14.7	W. 38.0 E. 13.5 8.3 32.0 9.3 33.9 39.5 15.0

Reduction of these observations gives the following results:

μ Aurigae $\Delta T =$	$-8^s.28$	Epoch $= 5^h\ 30^m$
α Aurigae	$-8\ .30$	Assumed δ T $= +4^s$
χ Aurigae	$-7\ .96$	$a = +0^s.10$
ζ Tauri	$-8\ .07$	$c' = \begin{cases} -0^s.10 \text{ circle west.} \\ +0\ .07 \text{ circle east.} \end{cases}$
$\Delta T =$	$-8^s.15$	

Summary of Chronometer Corrections.

Epoch.	ΔT.	δT.	Remarks.
1889.			
Feb. 16^d 6^h 8^m	[$-14^s.07$]		Evening signals, Feb. 16.
Feb. 16 8 0	$-13\ .77$		$\pm 0^s.03$.
Feb. 16 21 45	[$-11\ .53$]		Noon signals, Feb. 17.
Feb. 17 5 0	-9 (?)		From one star; azimuth unknown. Of no value.
Feb. 17 5 46	[$-10\ .22$]	$+3^s.92$	Evening signals, Feb. 17.
Feb. 17 21 45	[$-7\ .61$]		Noon signals, Feb. 18.
Feb. 18 5 0	$-6\ .42$		$\pm 0^s.02$. Chronometer jarred on way to station.
Feb. 18 5 55	[$-15\ .96$]		Evening signals, Feb. 18.
Feb. 18 7 30	$-15\ .70$		$\pm 0^s.03$.
Feb. 18 21 50	[$-13\ .29$]	$+4^s.01$	Noon signals, Feb. 19.
Feb. 19 5 30	$-11\ .99$		$\pm 0^s.04$.
Feb. 19 6 8	[$-11\ .81$]		Evening signals, Feb. 19.
Feb. 19 7 30	$-11\ .39$	$+3^s.84$	$\pm 0^s.02$.
Feb. 20 5 30	$-8\ .15$		

Values of ΔT obtained by interpolation are bracketed.

b. Clock Comparisons.

The (Howard) Mean Time Clock of the Lick Observatory is kept as nearly as possible $6^m\ 34^s.29$ fast of local time, and its face indicates therefore Pacific Standard Time. It is adjusted every morning at 10 o'clock so as to be very nearly right at noon, when signals are sent to the railroads. It beats the even-numbered seconds, omitting the 58th second of every minute, and the 52, 54, 56, and 58th second before every even fifth minute. In this way the second-beats can be readily identified at a distance.

The noon signals are repeated by hand at Sacramento (under the present arrangement) and cannot be depended upon for very accurate time.

Comparisons of Chronometer with the Howard Clock Signals.

February 15, 1889.

Noon, P. S. T. by Sacramento=Chronometer $21^h\ 33^m\ 20^s.8 \pm$.
No signals were received in the evening.

February 16, 1889.

No comparisons were made at noon.
In the evening the following comparisons were made:

Howard	$8^h\ 23^m$	$50^s.0$	=Chronometer	$6^h\ 4^m$	$41^s.4$
Howard	25	28 .0	=Chronometer	6	19 .6
Howard	25	50 .0	=Chronometer	6	41 .7
Howard	26	16 .0	=Chronometer	7	7 .8
Howard	27	48 .0	=Chronometer	8	40 .0
Howard	28	44 .0	=Chronometer	9	36 .2
Howard	29	36 .0	=Chronometer	10	28 .4

The signals came irregularly, with so many accidental pauses that the seconds could not be identified. The minutes and seconds given above were obtained with the aid of the difference of longitude found on other occasions. As the Howard Clock beats every other second only, there is no difficulty in doing this with certainty.

From the above comparisons, reduced to the epoch of the coincidence at $6^h\ 8^m\ 40^s$, and corrected for the rate of the chronometer,

Howard $8^h\ 27^m\ 47^s.98$=Chronometer $6^h\ 8^m\ 40^s.00$

In all these comparisons, the *coincidences* were observed as accurately as possible, and are given extra weight.

February 17, 1889.

Coincidence at Chronometer $21^h\ 43^m\ 4^s.0$
Noon, P. S. T. by Sacramento=Chronometer 21 43 22 .0 ±

In the evening no time observations could be made at Norman, on account of cloudy weather. The clock signals failed to come through automatically, and the San José operator was requested to strike his key in coincidence with the beats of the clock relay in his office, which he did, and the following comparisons were made:

Howard	8^h	0^m	$0^s.0$	=Chronometer	5^h	44^m	$39^s.0$
Howard	8	1	42 .0	=Chronometer		46	21 .0
Howard	8	3	0 .0	=Chronometer		47	39 .1
Howard	8	6	0 .0	=Chronometer		50	39. 7
Howard	8	13	0 .0	=Chronometer		57	40 .6
Howard	8	14	0 .0	=Chronometer		58	40 .9
Howard	8	15	0 .0	=Chronometer		59	41 .0

Reducing all comparisons to the epoch $5^h\ 46^m\ 21^s$, we have
Howard $8^h\ 1^m\ 42^s.05$=Chronometer $5^h\ 46^m\ 21^s.00$

February 18, 1889.

Noon, P. S. T. by Sacramento=Chronometer $21^h\ 47^m\ 14^s.2$.

In the evening the automatic signals of the Howard clock were very satisfactorily received, and the following comparisons obtained:

Howard	7^h	59^m	30^s	=Chronometer	5^h	48^m	$11^s.5$
Howard	8	3	0	=Chronometer		51	42 .0
Howard	8	4	0	=Chronometer		52	42 .3
Howard	8	5	0	=Chronometer		53	42 .4
Howard	8	5	38	=Chronometer		54	20 .5
Howard	8	6	0	=Chronometer		54	42 .5
Howard	8	8	48	=Chronometer		57	31 .0
Howard	8	10	0	=Chronometer		58	43 .4

Reducing these comparisons to the epoch $5^h\ 51^m\ 42^s$, we have for the result of all:
Howard $8^h\ 2^m\ 59^s.97$=Chronometer $5^h\ 51^m\ 42^s.00$.

February 19, 1889.

Sacramento signals beating irregularly.

Sacramento signals at	Chronometer	21^h	50^m	29.8
	Chronometer			43.4
	Chronometer			51.8
	Chronometer		51	7.3
	Chronometer			13.5
Noon, P. S. T. by Sacramento=	Chronometer	21	51	16±]

In the evening the automatic beats of the HOWARD clock were very satisfactorily received.

Howard	8^h	5^m	50^s = Chronometer	5^h	58^m	$25^s.0$
Howard	8	6	26 = Chronometer		59	1 .15
Howard	8	8	0 = Chronometer	6	0	35 .4
Howard	8	15	24 = Chronometer		8	0 .5
Howard	8	16	0 = Chronometer		8	36 .6
Howard	8	16	24 = Chronometer		9	0 .8
Howard	8	17	0 = Chronometer		9	36 .85
Howard	8	18	20 = Chronometer		10	57 .0
Howard	8	19	0 = Chronometer		11	37 .3
Howard	8	20	0 = Chronometer		12	37 .4
Howard	8	21	24 = Chronometer		14	1 .5

These comparisons, reduced to the epoch $6^h\ 8^m\ 0^s.5$, give as the result of all:

HOWARD $8^h\ 15^m\ 23^s.98$ = Chronometer $6^h\ 8^m\ 0^s.50$.

LONGITUDE FROM TIME OBSERVATIONS AND CLOCK COMPARISONS.

The corrections to one of the sidereal clocks at the Lick Observatory were determined by Mr. CHARLES B. HILL, and comparison with the HOWARD clock (No. 7) furnished the correction to the latter. As a check on the reductions, the interval by the HOWARD clock between the epoch of Mr. HILL's comparison and the signal used at Norman, was converted into the corresponding sidereal interval and added to the sidereal time of the comparison, the result agreeing in all cases within $0^s.01$ with the computed sidereal time of the HOWARD clock signal.

The corrections to the Howard clock are furnished by Mr. HILL in the following letter:

LICK OBSERVATORY,
SAN JOSÉ, CAL., March 15, 1889.

J. E. KEELER, *Esq., Astronomer Lick Observatory*:

MY DEAR MR. KEELER: I herewith communicate the corrections to clock No. 7, on Pacific Standard Time, for the nights on which signals were sent you at *Norman*, Cal.

I determined the corrections to the standard sidereal clock on the nights of February 16, 17, 18, and 19: The resulting errors and rates of clocks No. 8, No. 3, and No. 4 (compared each evening) were used to obtain a correction to No. 7 for the night of February 15th. The following errors of clock No. 7 are for an epoch sensibly coincident with that of the signals: This clock is

adjusted, with weights, each day at noon; the hourly rate is *less* than $\pm 0^s.02$.

February 15, P. M.	Correction to No. 7 = $+0^m\ 00^s.70$
February 16, P. M.	Correction to No. 7 = $+0\ \ 00\ .91$
February 17, P. M.	Correction to No. 7 = $+0\ \ 00\ .03$
February 18, P. M.	Correction to No. 7 = $-0\ \ 00\ .07$
February 19, P. M.	Correction to No. 7 = $+0\ \ 00\ .20$

Yours sincerely,

CHAS. B. HILL,
Assistant Astronomer, Lick Observatory.

REDUCTION OF CLOCK COMPARISONS.

February 16, 1889.

Howard	$8^h\ 27^m\ 47^s.98$ =	Chronometer	$6^h\ \ 8^m\ 40^s.00$
Howard ΔT =	$+0\ .91$	Chronometer ΔT =	$-14\ .07$
P. S. Time.	$=8\ \ 27\ \ 48\ .89$		
L. O. Sid. Time	$6\ \ 10\ \ 36\ .97$ =	Norman Sid. Time	$6\ \ 8\ \ 25\ .93$

Diff. of Longitude $=2^m\ 11^s.04$.

February 18, 1889.

Howard	$8^h\ \ 2^m\ 59^s.97$ =	Chronometer	$5^h\ 51^m\ 42^s.00$
Howard ΔT =	$-\ \ 0\ .07$	Chronometer ΔT =	$-15\ .96$
P. S. Time.	$8\ \ 2\ \ 59\ .90$		
L. O. Sid. Time	$5\ \ 53\ \ 37\ .02$ =	Norman Sid. Time	$5\ \ 51\ \ 26\ .04$

Diff. of Longitude $=2^m\ 10^s.98$.

February 19, 1889.

Howard	$8^h\ 15^m\ 23^s.98$ =	Chronometer	$6^h\ \ 8^m\ \ 0^s.50$
Howard ΔT =	$+0\ .20$	Chronometer ΔT =	$-11\ .81$
P. S. Time.	$8\ \ 15\ \ 24\ .18$		
L. O. Sid. Time	$6\ \ 9\ \ 59\ .88$ =	Norman Sid. Time	$6\ \ 7\ \ 48\ .69$

Diff. of Longitude $=2^m\ 11^s.19$.

The mean of the three nights gives for the difference of longitude,

$$2^m\ 11^s.07 \pm 0^s.05,$$

subject to correction for personal equation and "wave and armature time."

The probable error which has been assigned to the difference of longitude is somewhat greater than that determined from the discrepancy of the individual results.

Some of the other comparisons, not available for an accurate determination of longitude, give the following results:

Evening signals, February 17	$2^m\ 11^s.65$
Noon signals, February 17	2 10 .70
Noon signals, February 18	2 11 .19

The error of the noon signal is assumed to be zero. These values have been used merely as checks, and are not included in the final result.

c. Latitude Observations.

During the first few days of my visit to Norman I made many observations of the Sun, both for time and for latitude, as the evenings threatened to be cloudy. These observations have not been reduced, as better ones were subsequently obtained of stars. The simplest, and probably most accurate determinations of the latitude, were made by leaving the instrument in the plane of the meridian after the time observations, and observing the zenith distances of stars taken from the time list, as they passed the middle thread. By reversing the axis during the course of the measurements, and observing the same number of stars in each position of the instrument, both north and south of the zenith, errors of the zenith point (or index correction), flexure, and refraction are almost entirely eliminated. Latitude observations were made in this way on two nights, and the results are given in the following tables:

Meridian Zenith Distances.

February 18, 1889.

Aneroid=30in.21 — Temperature=32° Fah.

or, Barom. at 32°=30.in33 — True refraction=mean refr.×1.060

Zenith point=179° 59′ 20″.0

Star.	Circle.		App. Zenith Dist.	Refract'n.	ζ	δ	φ
	[East.]						
10 Urs. Maj.	182° 47′ 36″.3	N	2° 48′ 16″.3	0′ 3″.0	2° 48′ 19″.3	42° 13′ 16″.2	39° 24′ 56″.9
σ^2 Urs. Maj.	208 8 53 .3	N	28 9 33 .3	0 32 .7	28 10 6 .0	67 35 5 .9	59 .9
δ Hydrae	143 21 55 .5	S	36 37 24 .5	0 45 .4	36 38 9 .9	2 46 49 .2	59 .1
1 Draconis	222 22 25. 6	N	42 23 5 .6	0 55 .6	42 14 1 .2	81 49 0 .0	58 .8
ϑ Urs. Maj.	192 44 57 .7	N	12 45 37 .7	0 13 .9	12 45 51 .6	52 10 55 .8	64 .2
10 Leo. Min.	177 27 47 .0	S	2 31 33 .0	0 2 .7	2 31 35 .7	36 53 20 .4	56 .1
ε Leonis	164 51 34 .5	S	15 7 45 .5	0 16 .5	15 8 2 .0	24 17 1 .1	63 .1
μ Leonis	167 6 9 .7	S	12 53 10 .3	0 14 .1	12 53 24 .4	26 31 40 .9	65 .3
	[West.]						
π Leonis	210 49 9 .9	S	30 49 49 .9	0 36 .6	30 50 26 .5	8 34 29 .6	56 .1
α Leonis	206 53 22 .2	S	26 54 2 .2	0 31 .0	16 54 33 .2	12 30 28 .4	61 .6
λ Urs. Maj.	175 56 21 .9	N	4 2 58 .1	0 4 .3	4 3 2 .4	43 18 1 .2	58 .8
30 Urs. Maj.	153 17 13 .5	N	26 42 6 .5	0 30 .7	26 42 37 .2	66 7 36 .1	58 .9
β Leo. Min.	182 7 48 .8	S	2 8 28 .8	0 2 .2	2 8 31 .0	37 16 27 .8	58 .8
ρ Leonis	209 31 8 .9	S	29 31 48 .9	0 34 .6	29 32 23 .5	9 52 33 .5	57 .0

The circle reading given in the second column is corrected for error of level.

Meridian Zenith Distances.

February 20, 1889.

Aneroid=30in.195 — Temperature=44° Fah.

or Barom. at 32°=30in.315 — True refraction=mean refr.×1.034

Zenith point=179° 59′ 17″.6

Star.	Circle.		App. Zenith Dist.	Refract'n.	ζ	δ	φ
	[West.]						
ε Gemin.	194° 9′ 39″.8	S.	14° 10′ 22″.2	0′ 15″.1	14° 10′ 37″.3	25° 14′ 22″.5	39° 24′ 59″.8
ζ Gemin.	198 40 3 .7	S.	18 40 46 .1	0 20 .2	18 41 6 .3	20 43 52 .9	59 .2
λ Gemin.	202 39 35 .7	S.	22 40 18 .1	0 24 .9	22 40 43 .0	16 44 19 .1	62 .1
ι Gemin.	191 23 3 .7	S.	11 23 46 .1	0 12 .2	11 23 58 .3	28 1 2 .7	61 .0
α^2 Gemin.	187 16 19 .8	S.	7 17 2 .2	0 8 .2	7 17 10 .4	32 7 51 .0	61 .4
	[East.]						
β Gemin.	168 32 4 .5	S.	11 7 13 .1	0 11 .8	11 7 24 .9	28 17 34 .8	59 .7
φ Gemin.	167 37 36 .3	S.	12 21 41 .3	0 13 .1	12 21 54 .4	27 3 6 .3	60 .7
χ Gemin.	168 40 43 .4	S.	11 18 34 .2	0 12 .0	11 18 46 .2	28 6 15 .3	61 .5
27 Lyncis	192 23 40 .2	N.	12 24 22 .6	0 13 .4	12 24 36 .0	51 49 35 .5	59 .5
β Cancri	150 6 21 .1	S.	29 52 56 .5	0 34 .2	29 53 30 .7	9 31 31 .2	61 .9

The circle reading given in the second column is corrected for error of level.

Other Latitude Observations.

On February 18, the zenith distance of Polaris was observed, when about two hours from lower culmination, the resulting latitude being 39° 24′ 57″.6.

On February 20, three observations of δ Urs. Min. S. P. were made with circle west and two with circle east, when the star was near the meridian, the resulting latitude being 39° 24′ 56″.2.

Giving each of these two determinations the weight of one of the preceding observations, the mean of all (26 observations) is:

$$\varphi = 39^\circ\ 24'\ 59''.8 \pm 0''.3.$$

Personal Equation of Observers.

From observations made on two nights after my return to the Observatory it appears that Mr. Hill, recording on a chronograph, observes transits of stars between the equator and the zenith $0^s.11$ before myself, observing by the eye and ear method, or $K - H = 0^s.11$. The effect of this correction for personal equation is to diminish the difference of longitude, which is therefore:

$$2^m\ 11^s.07 - 0^s.11 = 2^m\ 10^s.96.$$

No correction will be applied for transmission time. The signals from the Observatory were repeated once, automatically, by the relay in the San José office, from which there was an unbroken wire to Norman.

Statement of Results.

The longitude of the Lick Observatory transit instrument is $8^h\ 6^m\ 34^s.29$ west of Greenwich. Hence the position of the altazimuth at Norman was

$$\varphi = 39^\circ\ 24'\ 59''.8 \pm 0''.3$$
$$\lambda = 8^h\ 8^m\ 45^s.25 \pm 0^s.05$$

The probable errors could easily have been reduced by continuing the observations, but as the results are of amply sufficient accuracy, and as I wished to return to the Observatory, I did not remain at Norman longer than was necessary for the purpose required.

The station occupied by Professor Pritchett was 195 feet distant from the altazimuth, in the direction S. 57° 43′ W. It was,

therefore, 104 feet=1″.03 south and 165 feet=$0^s.140$ west. Hence, finally, we have for the position of this station,

$$\varphi = 39^\circ\ 24'\ 58''.8$$
$$\lambda = 8^h\ 8^m\ 45^s.39$$

Respectfully submitted.

JAMES E. KEELER.

To Professor EDWARD S. HOLDEN,
Director of the Lick Observatory.

PART III. REPORTS OF THE ECLIPSE EXPEDITION OF THE PACIFIC COAST AMATEUR PHOTOGRAPHIC ASSOCIATION.

By Charles Burckhalter.

Chabot Observatory.
Oakland, California, February 26, 1889.

Professor Edward S. Holden, *Director Lick Observatory:*

My Dear Sir: According to promise and original intentions, I hand you herewith negatives and drawings obtained, and general report of the work done at the Total Solar Eclipse of January 1, 1889, by the Pacific Coast Amateur Photographic Association, acting under my direction, at Cloverdale, Sonoma County, California, together with the reports of many individual members of the Association, and others who were of the party.

When, about the beginning of October, I suggested to the leading members of the P. C. A. P. A. that they make up an eclipse party and accompany me to the path of totality, it was very gratifying to note the enthusiasm with which the proposition was received. The only question asked was whether their work would have any scientific value. When assured that it was in their power to solve such problems as the proper times of exposure necessary to photograph the different parts of the Corona, and permanently record its general outlines and extent, they entered heartily into the work, and a more enthusiastic, painstaking, and earnest party of gentlemen never came together for a similar purpose.

Out of this Association, composed as it is, almost entirely of active business and professional men, many of whom could ill afford the time required to prepare for and carry out our contemplated work, there were thirty cameras in line at our station on the day of the eclipse. In addition, there were a few amateurs not members of the Association, and a few professionals, who took advantage of our time signals and other arrangements. All were welcome, with the understanding that science should have the benefit of their efforts, if more successful than ourselves. The

Association did me the honor of making me an honorary member, and placed me in charge of the party, and I make this report as a member of their body.

Your pamphlet of instructions, or rather suggestions, did much to direct our efforts, as it brought out many questions that the members thought could be satisfactorily settled by photography.

Our original destination was Hopland, Mendocino County, but the bad condition of the roads, the great number of the party, the two days' extra time, which was, at the least, necessary to reach that place and return, all combined to cause us to be satisfied with the town of Cloverdale—the most westerly station occupied by any of the parties—although by so doing we lost about 14 seconds of the total phase of the eclipse. Then too, as it seemed to us, all other good points readily accessible had been selected by parties of Eastern astronomers, and we were anxious to make the line of observers as long as possible.

On the 29th of December, accompanied by Mr. Alpheus Bull, Jr., of San Francisco, Harry T. Compton, Charles P. Grimwood, and Marston Campbell (son of Director Campbell of this Observatory) all of Oakland, I went to Cloverdale to select a suitable station, to establish its position, and to make arrangements for the main body of our party, which was to arrive at the station on the evening of the 31st.

Our instruments consisted of sidereal break circuit chronometer, Negus, No. 1744; standard thermometer by Green, telegraphic sounder, lanterns, etc., from the Chabot Observatory. From my private Observatory we took the optical parts and finder of the 10½-inch equatorial silvered glass reflecting telescope by Brashear, Noday holosteric aneroid barometer, four jars gravity battery, sextant by Browning & Sharp of London, two small telescopes, plate holding parts of photographic camera, books, charts, etc.

Mr. John Roach, of San Francisco, kindly loaned us a good altitude barometer. Mr. Edward Dillon of Dillon & Co., San Francisco, loaned us a mean time chronometer, Wiedenham, No. 1233, set to Greenwich M. T., and a small astronomical transit, No. 778, by John Bliss & Co., N. Y. Mr. L. Sengteller of U. S. C. & G. S., gave us the use of a small telescope to serve as a finder for Mr. Lowden's camera, which was intended for long exposures; and a friend loaned me a good mercurial artificial horizon, which completed our instrumental outfit.

Careful transportation of the above instruments, especially the chronometers, was to be seriously considered, and, upon application to the General Superintendent of the San Francisco and N. P. R. R., I was furnished the following letter:

OFFICE OF SAN FRANCISCO AND NORTH PACIFIC RAILROAD,
SAN FRANCISCO, December 26, 1888.

To conductors, train, and station baggage masters, and agents:

You will pass "free" for bearer, all photographic and astronomical instruments offered, to Cloverdale and return, same being required by the members of the Amateur Photographic Association, for use at the Eclipse of the Sun on January 1, 1889.

As these instruments are very delicate, and easily put out of adjustment, and as any sudden jar will probably interfere with the success of the observations to be made, you will allow the members of the Association to place their instruments in the baggage car themselves, and you will render them all the assistance possible. You will, also, permit one or more persons to ride in car, to look after same.

Conductors will (when requested), permit members of the Association to carry instruments in the coaches, as some must be carried by hand. Agents will render every assistance possible at stations, and give their personal attention to see that instruments are carefully handled.

CHAS. THORN, JR.,
General Freight and Baggage Agent.

Mr. F. L. VANDENBURG, Superintendent of telegraphs for the Southern Pacific Railroad Company, and Messrs. FRANK JAYNES, Manager, and F. H. LAMBE, Superintendent of the Western Union Telegraph Company, arranged to have the Lick Observatory Pacific Standard time clock signals sent us at Cloverdale, on December 30th and 31st, and January 1st, at noon, and Mr. JOHNSON, the company's agent at Cloverdale, was instructed to give me the opportunity to compare our chronometers with the Lick Observatory clock. I may add that this was the first time the Lick Observatory time signal was ever sent to Cloverdale.

When we arrived at Cloverdale, I saw for the first time in twenty-six days a perfectly clear sky, and our prospects appeared brighter than for the past month.

On the morning of the 30th we quickly decided upon the station to be occupied, choosing a block of land in the midst of the little village, kindly placed at our service by our host, Mr. MINNEHAN, of the U. S. Hotel. The block was enclosed by a neat picket fence, and with the exception of a few large oak trees and a neat little cottage, was entirely vacant. A room in the cottage was cheerfully given us by Mr. M. P. DONNELLY for storage of instruments, and this kindness saved us considerable labor in carrying our instruments to and from the hotel.

During the afternoon of the 30th, we set up our transit instrument, the object glass of which is $1\frac{1}{16}$ inches aperture, and about $10\frac{1}{2}$ inches focal length; it is provided with a setting circle and striding level. The frame is movable in altitude, and one of the Y's in azimuth. The base is a circular brass disk, $6\frac{1}{2}$ inches in diameter, and the top plate carrying the pillars, the same diameter; can be clamped to the bottom plate when the instrument is approximately in the meridian, and the final adjustment made with the azimuth screw. The pier consisted of a joint of earthen sewer pipe, 16 inches at the base, and 12 inches at the top, and 30 inches high. It was placed upon solid ground, a strong box placed around it, and solidly packed with damp, sandy soil, which gave it sufficient stability. After leveling the top of the pier with liquid plaster of paris, a glass plate was placed on the top, and the bottom plate of the transit was attached to this with plaster of paris.

From a map showing the path of totality, a position was assumed as follows:

Longitude=122° 58′ 15″ west.

Latitude=38° 48′ 00″ north.

The transit instrument having been carefully collimated, and, from the assumed position, the time of transit of *Polaris* having been determined, the star was bisected at the proper time, and the instrument was very approximately in the meridian. Several pairs of stars, one north and the other south, were selected, the components of which would have azimuth factors of about equal value. The method adopted was to observe wires 1 and 2, then reversing circle and observing same wires, thus eliminating the errors of collimation.

The 1st pair observed was—

φ Persei, chronometer correction= $-0^h\ 1^m\ 42^s.50$.

ξ Piscium, chronometer correction= $-0\ \ 1\ \ 46.50$.

After making slight adjustments for azimuth deviation and again carefully leveling the axis, observed 2d pair—

γ Andromedæ, chronometer correction$=-0^h\ 1^m\ 44^s.00$.

β Trianguli, chronometer correction$=\quad -0\ \ 1\ \ 45.00$.

3d pair—

ν Persei, chronometer correction$=-0^h\ 1^m\ 43^s.80$.

ζ Persei, chronometer correction$=-0\ \ 1\ \ 45.00$.

The above results were better than I expected from so small an instrument, and from these observations we assumed the chronometer correction$=-0^h\ 1^m\ 44^s.50$.

We now compared our sidereal chronometer with mean time chronometer, WIEDENHAM No. 1233 (which had been compared with the Lick Observatory clock signal at noon), and found a variation of $0^s.38$.

Mr. COMPTON, assisted by Mr. CAMPBELL, had observed the Sun with a sextant and mercurial artificial horizon before and after noon, and *Polaris*, the same evening, for latitude, and from his observations for latitude and my own for time, we found the position of our station to be as follows:

Latitude$=38°\ 47'\ 43''$ N.

Longitude$=122°\ 57'\ 25''$ W.

By our altitude barometer we determined our station to be 317 feet above sea level.

We intended that these observations should be continued the next night, but the sky became densely cloudy after 5 P. M., and the above were the only observations made for local time. Mr. COMPTON, however, observed the Sun for latitude both the following days, and the above value for latitude is the result of all his observations. While I am not satisfied with the value of our longitude, it was the best that could be done under the circumstances.

The main body of our party arrived Monday evening, December 31st, and the densely clouded sky, and the unfavorable outlook for the next day did not, apparently, dampen their enthusiasm in the least.

After dinner we assembled in the large dining-room of the hotel, and each man's work was assigned to him, after fully considering his apparatus, plates, etc.

The proper time exposure to give our plates being unknown, we were determined that our work should be exhaustive, and

with that end in view we assigned exposures from the shortest possible to the longest possible to be obtained with our apparatus.

After a full explanation of the manner of counting time, etc., we drilled for two hours, and until every one thoroughly understood his part, and parted to meet next day at our station at 9 A. M. The sky at 6 A. M. was nearly free from clouds, and apparently clearing. By 10 A. M. every camera was in position, and drilling began. Each one was provided with one or more empty plate-holders, and each full holder was marked, or otherwise arranged, so the slide need not be fully drawn out, thus saving much time.

Our mode of working was as follows: Our break circuit sidereal chronometer was connected with a telegraph sounder and 4 jars of gravity battery, and at a given signal Mr. ALPHEUS BULL, Jr., began counting 1, 2, 3, etc., until "time" was called. This first counting of time represented the last few seconds before 2d contact, and the object was twofold—to bring every one to attention; and, as each one was instructed to look for the Corona and Sunflames before totality, he would only need to mark down the second counted, when it was first observed; and as Mr. BULL was to record the last second counted before time was called to establish the time of 2d contact, we could see at once how many seconds before totality the Corona or Sunflames were seen. As we had plenty of help, at the call of "time," another assistant, Mr. GEORGE H. STRONG, took up the count, and counted by the chronometer to 108 (the predicted duration of totality), when "time" would be called once more, and Mr. BULL would again take up the count until told to stop. This last count gave to all a measure of the length of time during which the Corona and flames might be seen after totality.

The cameras were formed in two long lines, running east and west, the lines being about thirty feet apart, north and south; the chronometers, telescopes, etc., being in the middle of the north line. Many of the photographers had removed the front combination of their lenses, thus doubling the length of focus and size of image.

Instead of the usual tripod, a strong plank was used, one end being supported by a trestle at the proper height, and the other end resting upon the ground. This arrangement proved to be simple and effective, being as rigid as desired.

There were only two cameras that call for special mention. The Association's camera, which was operated by Mr. W. H. Lowden, who heroically sacrificed his chances for a good picture by attempting the longest possible exposure, will be described in his accompanying report.

My own camera was arranged as follows: From my equatorial reflecting telescope I took the $10\frac{1}{2}$-inch speculum by Brashear, and placed it in the end of a wooden tube, made of 1-inch boards, 12 inches square inside, and $8\frac{1}{2}$ feet long. Near the upper end of the tube (the mirror being 84 inches focus) an opening was made 4 inches in diameter, and over this was placed the back end of my 5x7 camera, to keep the plate holder in position. In order to obtain a field large enough to show any possible extent of Corona, I had a large diagonal made by Mr. John A. Brashear, that gave me a field of $3\frac{1}{2}°$, the Sun's image being $\frac{13}{16}$ inches in diameter. The tube was carefully blacked inside, and numerous stops, with $10\frac{3}{4}$-inch opening, put in to break reflections. The front of the tube (when uncapped and exposures made) was entirely open, and many photographers predicted an entire failure from "fogging" the plates, and while I believed that more or less fog would appear on each plate, my judgment proved to be correct, as only two plates out of the eleven exposed were so badly fogged as to be comparatively useless. A pin prevented the slide of the plate holder from being entirely drawn out, and this caused a considerable saving of time. The telescope was provided with a finder, and in place of the ordinary cross wires (+), I placed a wire bent at right angles, something like the letter L.

The wire was size 22, and plainly visible on the sky at night, and was certainly a great improvement on the ordinary cross-wires, as when the image of the Moon was brought into the angle formed by the wires—the limb just touching each side—a very slight motion could be detected at once.

Mr. Lowden's camera was provided with a like arrangement, and worked so admirably that his negative of 41 seconds exposure is only slightly blurred.

This tube was then mounted upon a platform set at an angle of about 22° to the horizon, and a pair of slow motion screws, attached to the bottom of the tube, served to move the "camera" in altitude and azimuth. It was not intended to "follow" the Moon's motion, but these appliances were only to place the instru-

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ment in position quickly and correctly at the proper time. This part of the work was entrusted to Mr. CHAS. G. YALE, and for the last 15 minutes before totality he kept the "camera" (or rather telescope) correctly pointed. When the time of totality arrived, the preceding limb of the Moon just touched the center line of the plate, and the image was then allowed to move across the plate, this latter evil being of less consequence in short exposures than the jar that would necessarily have been given if we had attempted to "follow."

Each photographer had an assistant, who was provided with a card, divided into spaces marked 1 to 120 in heavy black type (so as to be easily read). This arrangement enabled the assistant to record, not only the duration of the exposures, but the exact epoch of totality at which the plate was exposed.

We began drilling as soon as all the instruments were in position, and after the first two trials, there were no blunders worth mentioning. We drilled for one and one half hours, and after lunching, we had about 45 minutes more drilling, for the benefit of a few assistants who arrived on the ground at noon, and then felt that the success or failure of our expedition depended entirely on the weather.

The party now consisted of the following persons:

Members of the Association—A. J. TREAT, S. C. PASSAVANT, CHARLES BURCKHALTER, O. V. LANGE, CHARLES G. YALE, P. CARLETON, C. F. MONTEALEGRE, J. W. STANFORD, J. V. A. REY, EUGENE FROST, SAMUEL C. PARTRIDGE, W. C. GIBBS, GEORGE W. DORNIN, WILLIAM LETTS OLIVER, J. H. JOHNSON, E. W. RUNYON, A. P. REDINGTON, W. H. CHAPMAN, W. H. LOWDEN, E. L. WOODS, GEORGE TASHEIRA, F. H. MCCONNELL, GEORGE W. REED, C. L. GODDARD, W. S. DAVIS.

My own assistants and those doing special work were:

ALPHEUS BULL, JR., HARRY T. COMPTON, MARSDEN CAMPBELL, C. P. GRIMWOOD, GEORGE H. STRONG, WILLIAM F. BOOTH, W. B. EWER, WM. M. PIERSON.

Recorders—H. W. SCHWERIN, WILLIAM N. MCCARTHY, W. C. EDES, ALFRED K. GIBBS, M. P. DONNELLY, F. C. DE LONG, GEORGE A. STORY, J. A. BAUER, E. S. GRAY, E. B. MOORE, GEORGE B. BAER, WALTER HENRY, M. SELIGSON, E. P. LIVINGSTON, F. S. WRIGHT, C. W. WILKINSON, HARRY PHELAN, MOSES CALLAN, THOMAS ANDREWS, MRS. C. L. GODDARD, MISS HERMIONE REY, MRS. E. S. GRAY, MRS. GEORGE TASHEIRA.

Sketchers—Mrs. George Roe, Miss Silvia Rey, Miss Truesdell, Miss Treat, Colonel C. Mason Kinne, Captain W. B. Hooper.

The following professional and amateur photographers not connected with the association were also present: I. W. Taber, A. C. Burnham, W. B. Tyler, Louis de F. Bartlett, Bert Remmel.

The sky was just about one quarter covered by generally light, but sometimes heavy clouds, which gave us great anxiety.

Another source of danger came at one o'clock from an immense column of smoke, several hundred feet high, from a burning brush pile a quarter of a mile south from our station, on the property of a Mr. Farmer. When we sent a messenger in hot haste, with a request that the fire be put out, the obliging old gentleman, although a confirmed invalid, drew the water himself and did not tire until the last vestige of smoke had disappeared.

The clouds drifted lazily by from the west with tantalizing regularity, and our anxiety became intense when, at 7 minutes before the predicted time of totality, a light cloud partially obscured the now rapidly narrowing crescent of the Sun, and we feared our work would be a total failure. When the Sun was about in the middle of the cloud, it was surrounded by a magnificent halo, the colors being most gorgeous, resembling the colors from the naked rays of an electric arc light, rather than a natural rainbow.

Mr. Oliver, at about 60 or 70 seconds before totality, took a photograph of the Sun, a copy of which will be transmitted herewith, showing the Sun still covered by the light cloud, with all the surrounding sky clear. This picture we have named "a narrow escape," and it was uncomfortably narrow, the cloud clearing only 30 seconds before second contact.

It was not our intention to observe contacts, and therefore first and last contacts were not taken. There being few or no experienced observers to put at this work, I am not certain of 2d contact nearer than one second, but the duration was very certainly correctly observed.

The meteorological instruments were being cared for, the artists were ready with the cards expressly prepared for drawing the Corona, and every man was in his appointed place.

Mr. Compton with a sextant, and Mr. Wm. M. Pierson with a $3\frac{1}{2}$-inch telescope, were observing for 2d contact. All being ready and the time being now close at hand, I gave Mr. Bull the signal and the 1st count began, which was only interrupted at "52" by

the 1st call of "time" by Messrs. COMPTON and PIERSON simultaneously.

This was the signal for Mr. STRONG to begin his count, and the photographers and others to begin their allotted tasks. The conscientious and painstaking work of this party of volunteers will be more fully appreciated when it is mentioned that not one half of them spared the time necessary to even look at the Corona, and therefore did not see it at all during totality, while some few "just looked for a second." To the majority of photographers the beautiful phenomena attending a total solar eclipse are yet only to be seen in drawing and photograph, and the opportunity of a lifetime was allowed to pass, for the sake of the scientific results hoped for. I believe our drilling had something to do with this, as all had been advised to use the first 10 seconds in seeing the Corona; and, while our party cannot be considered as being made up of scientists and astronomers, their disinterested work is worthy of all praise.

At the instant of Mr. STRONG's count of "104," "time" was called, and the first gleam of the sunlight found many shutters open—my own among the number. We could not realize that 104 seconds had passed, and that our work was done—well done, we hoped. We now watched the inner Corona, which was easily visible around three quarters of the Moon's limb, and saw it fade slowly and majestically away. The greater number who observed it followed it for about 45 seconds, a number followed it to 50 and 55 seconds. I lost it at 55 seconds, while Mr. TREAT, the President of the Association, and Mr. STRONG followed it for 69 and 70 seconds, respectively. This was much longer than before totality, while several observers saw the Corona at the count "42" (10 seconds before totality), Mr. GIBBS claims to have seen it at count "9," 43 seconds before totality. I saw it myself at count "43," or 9 seconds before the total phase.

Our greatest disappointment was the almost total absence of those prodigious sunflames which were represented in almost every picture of a solar eclipse we had ever seen. Several saw slight pink points within the inner Corona; but they were extremely minute, and nothing in the least grand about them at all; but the Corona was beautiful—superbly, magnificently beautiful. Another disappointment was that the general light during totality was much brighter than full moonlight—my own judgment would make it four, if not five times, brighter than full

moonlight. I think our experiments with the sensitometer, to be mentioned hereafter, will be interesting.

We had no need whatever for our lanterns, either for the chronometers or any other work except the thermometers, and no one was in the least incommoded for want of more light. I could have read with ease ordinary newspaper print. Two minutes after third contact the sun was again obscured by a cloud for several minutes. It was this cloud that obscured the view of a small party to the west of our station.

The face of sidereal chronometer, NEGUS 1744, read by Mr. BULL at the call of "time"$=20^h\ 23^m\ 31^s.00$, which, after correcting for error and rate and reducing to Pacific Standard time, $=1^h\ 46^m\ 43^s.25$.

By chronometer, WIEDENHAM, No. 1233, compared with Lick Observatory time signal, and after correcting for error$=1^h\ 46^m\ 45^s.25$.

The duration of totality=104 *sidereal seconds.*

The time of 2d contact and duration of totality as computed by Lick Observatory, from the data of the English Nautical Almanac, was

2d contact$=1^h\ 46^m\ 44^s$.
Duration= 1 48 .

The foregoing readings of the chronometers, show a difference of 2 seconds. Mr. BULL had had considerable practice since our arrival at our station, and I have confidence in his work, while the assistant who read the mean time chronometer had had no previous practice. I assume, therefore, that Mr. BULL's reading was correct, and that 2d contact took place at the predicted time very nearly; but, as mentioned heretofore, there may easily be an error of one or even two seconds.

Immediately after the counting stopped the great crowd of visitors and friends who had been admitted to the enclosure—on promise of good behavior—burst into three hearty cheers, followed by great cheering for everything and everybody, amidst the wildest enthusiasm.

The different drawings were now finished, the time the Corona could be seen before and after the time of totality was permanently recorded, and all handed to the proper person, *without comparing notes with the work and observations of others.*

After the totality, we left the fourth contact to take care of itself, and proceeded to pack our instruments in order to leave on the special train at 3:30.

Colonel J. M. DONAHUE, the owner of the San Francisco and North Pacific Railroad, kindly gave us a special car, and we feel under obligations to this gentleman for many other favors and attentions. He was one of the most enthusiastic observers at our station.

The development of my exposed plates was entrusted to Mr. LOWDEN, to whose good judgment I am indebted for any excellence of detail they may show. The plates used were made by Dr. S. C. PASSAVANT, of two grades, known as H. L. and C. I. P.

Passavant H. L. plate sensitometer test=15.

Passavant C. I. P. plate sensitometer test=23.

The 11 plates exposed were as follows:

No. 1. C. I. P. plate exposed 1 sec. from the 2d to 3d sec. of totality.
No. 2. C. I. P. plate exposed 1 sec. from the 8th to 9th sec. of totality.
No. 3. C. I. P. plate exposed 2 sec. from the 16th to 18th sec. of totality.
No. 4. C. I. P. plate exposed 2 sec. from the 24th to 26th sec. of totality.
No. 5. H. L. plate exposed 1 sec. from the 35th to 36th sec. of totality.
No 6. H. L. plate exposed 2 sec. from the 41st to 43d sec. of totality.
No. 7. C. I. P. plate exposed 9 sec. from the 53d to 62d sec. of totality.
No. 8. C. I. P. plate exposed 5 sec. from the 66th to 71st sec. of totality.
No. 9. H. L. plate exposed 5 sec. from the 77th to 82d sec. of totality.
No. 10. H. L. plate exposed 10 sec. from the 89th to 99th sec. of totality.
No. 11. H. L. plate exposed 1 sec. (?) from the 104th to (?) sec. of totality.

The card used for recording by my assistant, Mr. BOOTH, will accompany the negatives sent to the Lick Observatory. That the times are given correctly may be known when I mention that he did not once remove his eyes from the card, and did not see the Corona at all.

The negatives can be described as follows:

No. 1. Camera jarred while uncapping; partly spoiled.
No. 2. Fair, but plate met with an accident.
No. 3. Best of all, showing greatest extent of Corona.
No. 4. Over exposed and considerably fogged.
No. 5. Shows inner Corona best of all.
No. 6. Very good for both inner and outer Corona.
No. 7. Badly over exposed and badly fogged.
No. 8. Over exposed.
No. 9. Almost as good as No. 3.
No. 10. Over exposed and badly fogged.

No. 11. Was exposed for about one second before the end of totality, and just a fraction of a second after the reappearance of sunlight. I only intended exposing ten plates, and this was merely to fill in the time, and, although it is the result of a mere

accident, I think it one of the most valuable of all my negatives, showing as I believe, the phenomenon of "Baily's Beads."

It is much to be regretted that the great delicacy of detail shown in the negatives cannot be shown in the prints, any picture I have yet seen being considered very excellent if it will show twenty per cent of the detail to be seen in the negative, although glass positives will show perhaps fifty per cent.

In closing, I wish to thank individually and in the name of the Association, all those who have by their kindness and assistance contributed to the success I believe we have achieved; and I bespeak for the Pacific Coast Amateur Photographic Association the credit to which they are entitled by their disinterested efforts to aid the science of astronomy.

I am, sir, yours with respect,

CHARLES BURCKHALTER,
Astronomer in charge of party.

CALIFORNIA ACADEMY OF SCIENCES,
SAN FRANCISCO, CAL., March 9, 1889.

DEAR MR. BURCKHALTER: Perhaps you remember that we were talking a few days ago of the "shadow-bands," and that I told you I had communicated my observations concerning them to Dr. JOSEPH LE CONTE. It has occurred to me that it might possibly interest you to have a record of them.

My attention was called to them by TOWNSHEND S. BRANDEGEE, who was of our party, and who had observed them a few years before in Colorado.

We were standing at the edge of a broad road, running nearly at right angles to the advancing shadow of the eclipse. The bands appeared just before totality (nobody looked for them afterward). The dark bands appeared to have tolerably defined edges, and alternated with lighter intervals, which, according to my impression, were considerably wider than the first. I should say, estimating roughly, that the dark bands were perhaps four inches in width, and the lighter ones twice as wide. This is, however, only the record of a hasty impression. No doubt, Mr. BRANDEGEE's observations would much correct mine. They seemed to be perfectly straight, but as they were only observed for a short portion of their length (the width of the road), this may easily have been

an error. They advanced in the direction of the eclipse with a steady rather slow motion, roughly estimated at perhaps ten feet in a second.

It seems to me that the phenomenon is produced by the diffraction of a beam of light, the narrow strip of sun just before totality answering to the slit in a shutter, by which diffraction bands are ordinarily produced.

If you think this would be of any interest to Professor HOLDEN, you are at liberty to use this letter.

Sincerely yours,

MARY K. CURRAN.

CALIFORNIA ACADEMY OF SCIENCES,
SAN FRANCISCO, CAL., March 26, 1889.

Professor HOLDEN:

DEAR SIR: You are perfectly welcome to my slight observations, which might have been more exact, and so of greater value, if, being my first Total Eclipse of the Sun, I had not felt bound to take a general view of the phenomena.

Some observations just made on mirror shadows have made me think that possibly the apparent greater width of the light-bands, as I remember them, was due to the merging of the shadow into the dun color of the road—only that portion of the band which was darker than it making an impression upon me.

Sincerely yours,

MARY K. CURRAN.

NOTE.—The preceding letters have been communicated to Professor W. UPTON, of Brown University, at his request.

SAN FRANCISCO, February 5, 1889.

Mr. CHAS. BURCKHALTER, *Chabot University, Oakland, Cal.:*

DEAR SIR: I have the pleasure to hand you herewith my report, with a description of the results obtained during the recent Total Eclipse of the Sun, as seen from Cloverdale, in Sonoma County, Cal., on January 1st of the present year.

I first saw the Corona on the westerly limb of the Moon, but cannot give the exact instant, as my attention was called away for a moment during that time, and upon glancing up, the Corona

was showing plainly. I did not attempt to note its duration after totality. I had read that a very marked shadow of the Moon could be seen traversing the landscape, as the moment of totality drew near, and although I looked carefully for it, I could see no such phenomenon, either before or after totality.

The light from the Corona was much brighter than I had anticipated, although not at all trying to the eyes. The inner Corona appeared to me to be of a light steely-blue color, the outer of a pure soft white, shading gradually off to nothing. I should judge that the Corona at its maximum point extended about two diameters of the Moon to the west of the Moon, and about one and one half diameters to the east. There was a very perceptible fall of temperature during totality.

With the assistance of Mr. E. P. Livingston, of Cloverdale, I made five exposures, and will submit four of the negatives herewith.

The apparatus used by me consisted of a Gibbs 5x7 camera, mounted on my ordinary tripod, without other steadiment, as I found no difficulty in getting the proper elevation.

My lens consisted of the front combination of a Darlot No. 2 rapid lens, having a focal length of seventeen inches; (normal focal length, nine inches.)

I had six Blair feather-weight holders, and one dozen Seed 25 sens. plates, one half with backs blackened, and one half without. The lens was "stopped down" with F/32 diaphragm.

The negative numbered "one," which I hand you herewith, was exposed for one second, being from the eighth to the ninth second of totality.

No. 2, was an instantaneous exposure, made on the 31st second.

No. 3, was of ten seconds, being from the 53d to the 63d second.

The fourth negative which I made, being a duplicate of No. 3, I have retained.

No. 5, was of one second duration, and exposure made one second after totality had ceased.

These plates were all developed with the "Burnham Formula," for development, taking from twenty minutes to half an hour each in development; I noticed no difference in results obtained on the plates with backs blackened from those without.

Respectfully submitted.

Geo. W. Dornin.

San Francisco, January 25, 1889.

Mr. Charles Burckhalter:

Sir: I have the honor to present to you a report of my personal observations of the Eclipse of the Sun on January 1, 1889, as seen at Cloverdale.

The inner Corona was first visible to me, on the dark limb of the Moon, 43 seconds before totality, and the outer Corona at 26 seconds previous to totality.

A drawing of the Corona was afterwards made from memory, and handed to the committee.

My last sight of the outer Corona was 20 seconds after totality.

I did not see Sunflames at any period of the eclipse.

I could not see any shadow of the Moon, traveling in any direction.

The Corona appeared to me of a steely blue color, quite intense next to the Moon, and shading off at the extremities into the sky.

I did not notice the polar wisps with the naked eye.

I should judge that the Corona extended about two diameters of the Sun (perhaps a little more) toward the west, but not nearly so much toward the east.

My son, Alfred K. Gibbs, acted as recording assistant for me.

I exposed two plates successfully—one H. L. Passavant, sensitometer 15, for one second, from 11 to 12; one C. I. P. Passavant, sensitometer 22, for one second, from 31 to 32. These negatives herewith to be forwarded to the Lick Observatory.

The lens used was a Lancaster's "Instantograph" (single view lens) 22 inches focus, and stopped to F/22.

The camera was a "Gibbs," 5×7, with cone extension, mounted on inclined board.

The exposures were made with the cap of the lens.

Trusting that these few facts may prove of some use to you, I remain, sir,

Yours respectfully,

W. C. Gibbs.

University of California, College of Dentistry,
San Francisco, January 30, 1889.

Mr. Chas. Burckhalter:

Dear Sir: I transmit to you as part of my report on the Total Eclipse of the Sun, January 1, 1889, four negatives of the Corona, numbered and marked according to directions.

I saw the Corona a few seconds before and a few seconds after totality, but do not know how many. During totality the greatest extent of the Corona seemed to be in general east and west direction, in width nearly equal to the Sun's diameter, and in length two diameters more or less from each side of the Sun.

I did not notice any Sunflames nor the shadow of the Moon on the earth.

Assisted by my wife, I exposed five plates as follows:

No. 1. PASSAVANT, H. L. from 5th to 6th second, time 1 sec.

No. 2. SEED, No. 26, from 20th to 22d second, time 2 sec.

No. 3. PASSAVANT, H. L. from 48th to 59th second, time 11 sec.

No. 4. SEED, No. 26, from 74th to 86th second, time 12 sec.

No. 5. PASSAVANT, H. L. from 102d sec. to 2 (?) sec. after totality.

The first three and the fifth are to be forwarded to the Lick Observatory. The fourth was badly jarred. I used the rear lens of the DARLOT No. 2, the front lens being removed. The double lens had a focus of $8\frac{1}{2}$ inches; the one I used was 17 inches focus.

The diaphragm was $\frac{7}{8}$ inches, or $\frac{F}{19+}$

The camera was an ANDERSON square, 5x7 in., extension front, mounted on the inclined board and trestle provided by you.

Yours respectfully,

CLARK L. GODDARD,
1326 Chestnut St., Oakland.

FRUITVALE, ALAMEDA COUNTY, January 29, 1889.

CHARLES BURCKHALTER, *Esq.*, *Chabot Observatory*, *Oakland*, *Cal.:*

DEAR SIR: Herewith please find five negatives taken by me as a member of your party, of the Total Solar Eclipse of January 1, 1889, at Cloverdale, Sonoma County, Cal. My recording assistant was Mr. M. P. DONNELLY, of Cloverdale.

I exposed six plates successfully, obtaining an impression of *Mercury* on each one.

No. 1 was exposed 4 seconds, between the 6th and 10th second of totality.

No. 2 was exposed 10 seconds, between the 22d and 32d second of totality.

No. 3 was exposed 11 seconds, between the 35th and 46th second of totality.

No. 4 was exposed 10 seconds, between the 55th and 65th second of totality.

No. 5 was exposed 15 seconds, between the 70th and 85th second of totality.

No. 6 was exposed 8 seconds, between the 100th second of totality and the 4th second after totality.

Nos. 1, 2, 4, 5, and 6 are the negatives inclosed to be forwarded to the Lick Observatory.

The lens used was the back combination of a BECK 5x8, with diaphragm F/4, and an 18-inch focus.

The camera was a 4¼x6½ WATERBURY, with a tin tube 12 inches long for an extension, supported on inclined board and trestle.

The plates used for Nos. 1 and 2 were SEED No. 26; for Nos. 3 and 4 SEED No. 22; and for Nos. 5 and 7 SEED No. 26.

Yours truly,

C. P. GRIMWOOD.

Mr. CHAS. BURCKHALTER, *Chabot Observatory:*

DEAR SIR: I had the pleasure to attend, as a member, the Pacific Coast Amateur Photographic Association's Eclipse Observation Expedition, which, under your management, set out for Cloverdale, California, on December 31, 1888.

It is unnecessary that I make any references to the general outline or preparations of the work undertaken. I will confine my report to the results of my work and experiences, and condense it so far as possible. As you are aware, few data were available to guide us in selecting apparatus, or in determining what methods of working would give the best results; what plates to use, etc. Our work was of necessity wholly experimental.

We had been assured by the astronomers that our ordinary cameras could yield results of considerable scientific value. With this assurance, I made but little change in my regular photographic outfit.

My outfit consisted of the following:

A camera taking a 5-inch by 7-inch plate.

A very rigid tripod, with special contrivance screwed to the head of tripod, whereby the camera could be altered in position, both horizontally and vertically.

A VOIGTLÄNDER portrait lens number A 3, 2-inch aperture, with back lens removed, which gave about 14 inches back focus; $\frac{F}{16}$ diaphragm was used.

Six plate-holders, containing 2 PASSAVANT H. L. plates, 8 PASSAVANT C. I. P. plates, 2 SEED 22 plates.

The plate-holders were fitted with rods of brass screwed into plate-holders between slides, and having buttons on ends to prevent the entire withdrawal of slides.

A finder, shade glasses, lantern, etc.

Having taken position in the field, I firmly imbedded the legs of my tripod in the ground, drove a stake between them, and, to secure greater rigidity, connected tripod head to stake with lashings. The hinged rising board contrivance with adjusting screws was placed upon tripod, the camera set, and found to be perfectly steady. On an improvised table at my side I arranged (2 minutes before totality) my plate-holders, previously numbered, in such order that the rapid and slow plates alternated. This completed my arrangements.

Before totality I, together with all other members, drilled in routine of work to be done, using an empty plate-holder for exposures. Mr. GEO. A. STORY rendered me the greatest assistance in recording my exposures upon a card furnished him for the purpose.

I regret to say that before and during totality I gave no special attention to the Corona or phenomena in general, being over anxious to secure the greatest possible number of exposures.

Before totality (I did not record first appearance) I saw a large coronal ring extending from the side of the Moon. Its diameter was much greater than that of the Moon, with a small segment cut off where it apparently touched the Moon.

It had the appearance of a huge bright soap bubble, without the iridescence. I had but a few seconds' glance at the Corona during totality, did not study its structure, and only noticed its general outlines. I was very much surprised at the brilliancy of the inner Corona, and the brightness of the sky. I had expected greater darkness of sky, and less intensity of inner Corona.

I obtained seven exposures during totality, and one at four seconds after totality.

Following is a list of exposures:

(Figures represent seconds after totality began.)

4	to	7—H. L. Plate—No. 1.
16	to	19—C. I. P. Plate—No. 2.
30	to	32—H. L. Plate—No. 3.
40	to	44—C. I. P. Plate—No. 4.
54	to	64—Seed 22 Plate—No. 5.
76	to	86—C. I. P. Plate—No. 6.
97	to	98—C. I. P. Plate—No. 7.
108	to	109—C. I. P. Plate—No. 8.

The manner of developing my negatives, in view of the results, is not of sufficient importance to note here; suffice it to say that processes were varied, using pyro and hydroquinon developers.

Results about the same. *Mercury* is shown in all but last plate. I shall not enter into any description of the plates. My negatives are to me disappointing in many respects.

First—The photographic image is more unlike the visual one than I expected.

Second—The actinic effect of the sky was so great as to fog plates which had long enough exposure to show somewhat the extent of the Corona.

Third—The reflection of the bright image of the inner Corona from the back of the lens completed the work of obliterating structural detail, which the lens, from its nature of reducing the image, tended to do. The lens, in reducing the image, brought the structural lines of brightness so close together that the spaces between them were solarized. Take, for example, the brushes or wisps of light radiating above and below the Moon. The lens so reduced and brought together the images of these bright lines of light on the sensitive plate, that their close proximity of brightness shed a halo over the shady intervening spaces, with the result of complete solarization of the latter.

The negative image, therefore, shows the inner Corona as a solid mass of light.

Fourth—The small extent of Corona on plates of even the longest exposure. An exposure which fogged the plate was not long enough to register nearly the full extent of the visible Corona. In fact, I believe the ends of the coronal streamers had considerably less actinic power than had the sky, and I am convinced that the Corona's extreme light cannot be photographed with an ordinary camera, unless, probably, the sky be considerably less bright than it was in this eclipse, and the sky about the Moon be shut off as much as possible by a hood or tube projecting in front of lens. Possibly these extremities of the streamers *may* be photographed *negatively;* that is, the coronal ends would be lighter than the sky on the negative.

Generalizing from my experiences, I am led to believe that the best apparatus for photographing an eclipse is such as will give a magnified image of the Corona. Magnification is to my mind the only method of obtaining a good negative of the inner Corona—its strong light must be spread over a large surface of plate if you would register structural detail—the converse method *might* be best for the outer Corona with its faint light. Such an apparatus must be used for the outer Corona especially, as will, in

giving an image, absorb the least actinic light, and must be made to follow the Corona by clockwork.

This seems to me imperative in photographing the outer Corona. For the actinic effect of the extremes of the coronal streamers is so slight that with a stationary camera they have not force enough to register an impression, moving as they do over the field of the plate. In other words, enough actinic light waves are not "piled up" *one upon the other* on the plate to make any permanent or perceptible impression.

Further, the Corona alone as much as possible should be in the optical field, all surrounding skylight excluded.

No one plate, of course, will satisfactorily register such extremes of intensity as obtain between the outer and inner Corona.

I have dwelt upon the disappointing features of my negatives; whatever of value may be in the negatives I leave to discovery by the astronomers to whom they will be surrendered.

In conclusion, permit me to say, that I shall always regard the day of this eclipse as a memorable one; and, as a Native Son of the Golden West, feel proud that our California climate acquitted itself so well.

I cannot thank too highly or adequately express my obligations to those gentlemen, yourself at their head, who so successfully managed our expedition, who sacrificed themselves for the good of all and the interest of science in the various duties of preparations, observing contacts, counting time and recording exposures, etc., the labor without which our efforts would have been of little or no value. I only regret that my efforts were not more fruitful to justify their labors.

To Mr. Geo. A. Story, who kindly recorded my exposures, I feel particularly grateful, giving up, as he did, time which he might have devoted to admiring the eclipse. His kindness is the more conspicuous, as he was a stranger to me.

With congratulations to you, and thanking you for the interest you incited in, and the help you afforded this expedition, I remain,

Yours very truly,

James H. Johnson,
Secretary P. C. A. P. A.

San Francisco, February 13, 1889.

BERKELEY, January 30, 1889.

Mr. CHARLES BURCKHALTER:

DEAR SIR: Totality was seen by me as fifty-two was counted. I did not notice the duration of Corona after totality; did not see Sunflames; did not see shadow of Moon. C. W. WILKINSON was my Recording Assistant. I exposed five plates:

No. 1—¼ sec., Passavant C. I. P.—14ˢ of totality.
No. 2—1 sec., Passavant C. I. P.—34–35 of totality.
No. 3—4 sec., Passavant H. L.—60–64 of totality.
No. 4—2 sec., Passavant H. L.—88–90 of totality.
No. 5—3 sec., Passavant H. L.—105–108 after totality.

Four negatives to be sent to the Lick Observatory; one was broken, No. 3.

Lens, 8x10 DALLMYER, 12½-inch focus; stop, $\frac{F}{16}$.

5x8 ANTHONY camera.

O. V. LANGE.

To Mr. CHAS. BURCKHALTER, *Chabot Observatory, Oakland, Cal.:*

MY DEAR SIR: Herewith I hand you two photographic negatives of the Total Solar Eclipse of January 1, 1889, taken by me at Cloverdale, California.

These negatives were obtained in the following manner: Taking an ordinary 11x14 camera, I inclosed it in a wooden box open at each end. This box was hinged at one end to a stout plank which rested (when in position) on two wooden trestles. Under the other end of the box, and between it and the plank, was placed a screw, which, when operated, raised or lowered the end. At one side of this end was placed another screw which, when operated, moved the box in azimuth.

On top of the box I mounted a 1½-inch telescope, carefully adjusted, so that when an image was seen in the centre of the cross wires, it was at the same time projected on the photographic plate of the camera exactly in the centre.

I used a rapid rectilinear lens, made by R. & J. BECK, of 24 inches equivalent focus. In this I used a 3-inch diaphragm, thus reducing the aperture to F/8. The plates were a special emulsion, prepared by Dr. S. C. PASSAVANT, of San Francisco, and registered 12 on WARNECKE's sensitometer.

At the beginning of the first count by the assistant, which I learn was some 52 seconds before totality, I brought the Moon's image into the centre of the cross wires in the telescope, and by

aid of the screws, above mentioned, kept it there. The wires were placed in the form of an L, and enabled me to see the slightest movement much more readily than if the wires were crossed in the usual way. When "time" was called for totality, I occupied the first 15 or 16 seconds in looking at the Corona with the naked eye, and again getting the image fairly centered. At 19 seconds after totality my assistant, Mr. J. W. STANFORD, removed the cap from the lens and at 60 replaced it, thus giving an exposure of 41 seconds. During this time I kept the Moon's image as steadily as possible in the centre of the wires of the telescope. After reversing the plate-holder and allowing the camera to cease vibrating, the lens cap was removed at 76 seconds after totality, and replaced as "time" was called at 104 seconds. This plate had, therefore, 28 seconds exposure. I have marked the first plate No. 1, and the second No. 2.

The plates were of course very much over-exposed. I used the ordinary pyrogallic acid and carbonate of potash developer, modifying it, however, by using three times the usual quantity of water. A normal developer would have produced a thin foggy image, while restraining the action either by the use of bromide or by reducing the volume of potash would result in clogging up the inner Corona hopelessly. As development proceeded I was compelled to add more water, the action being exceedingly rapid. The image on the 41 second plate made its appearance in 7 seconds, and was fully developed in 6 minutes. I did not observe any difference between this and the 28 second plate worthy of note.

An examination of the negatives shows the inner Corona a mass of light without detail, while the extreme ends are developed into the light of the sky. This would seem to prove that the limit of the photographic image had been reached in both cases, and while the eye may have been able to discern the contrast between the faint light of the Corona and the sky for a greater distance than the negatives show, the photographic value of these faint rays seems to have been no greater than that of the sky at the same point.

The planet *Mercury* is shown on both of these negatives.

W. H. LOWDEN.

NOTE.—See Figure 1 of this volume.

SAN FRANCISCO, February 1, 1889.

CHAS. BURCKHALTER, *Esq.:*

DEAR SIR: In answer to the circular issued by the President of the P. C. A. P. A., I take pleasure in placing before you the following data respecting my work at the Cloverdale expedition.

Recording Assistant—FRANK S. WRIGHT.

Camera—Scovill's "Albion" compact, $6\frac{1}{2}$x$8\frac{1}{2}$.

Lens—Morrison leukoscope—3-inch aperture—19 in. equivalent focus—no stop.

Plate—Eastman's American film—sensitometer 22—transferred to and left on glass to avoid any possible aberration in backing with the gelatine skin and stripping from the glass.

Exposures—Ten in all—two before, four during, and two after totality.

The two before and the two after totality were solarized.

The four exposures during totality were as follows:

No. 1—Three seconds between the 18th and 21st of totality.
No. 2—Ten seconds between the 34th and 44th of totality.
No. 3—Twenty seconds between the 55th and 75th of totality.
No. 4—Fifteen seconds between the 86th and 101st of totality.

Herewith I send you two negatives for delivery to the Lick Observatory. No. 1. Three seconds exposure—between the 18th and 21st of totality, and No. 4, fifteen seconds exposure—between the 86th and 101st of totality.

N. B.—Instead of negatives I will hand you two corresponding positives made by Mr. TYLER through the camera, as soon as he has them ready for me.

Being very busy with my camera and wishing to do good work with it I paid no particular attention to the time before and after totality, when the Corona was first visible to me. During the duration of my exposures I observed the phenomena, but was unable to distinguish any Sunflames as distinct from the rays of the Corona.

I used no especial apparatus for the occasion, and with the exception of turning back the front leg of the Fairy tripod and bracing with string the front of the camera, I followed the usual mode of procedure.

Very respectfully,

C. F. MONTEALEGRE.

SAN FRANCISCO, February 9, 1889.

C. BURCKHALTER, *Esq.*, *Chabot Observatory*, *Oakland*, *Cal.:*

DEAR SIR: I beg herewith to present to your consideration the result of my photographic work and observations on the occasion of the P. C. A. P. A. Eclipse Expedition to Cloverdale on January 1, 1889.

The camera used I especially constructed for the purpose. It consisted of a quadrangular wooden tube 8″x8″ and 32″ long. The front end had a head $1\frac{1}{2}$″ thick, bored to carry the lens tube; the hole was lined with velvet, which allowed the lens tube ample latitude to slide, for fine focussing, without leaking light. At the rear end was fitted the ordinary reversible back of a half plate camera. The lens was the front combination of a LAVERNE R. R. lens, reversed, the focus being 32 inches, and the diaphragm used was F/22. In place of a tripod I used an inverted rectangular channel, or trough, made of three boards, each 8 feet long, one end of the channel resting on the ground and the other on a trestle; this made a very rigid and exceedingly convenient stand. The whole outfit was rudely constructed, but proved extremely practical and thoroughly successful.

I made two exposures before totality, six during totality, and one immediately after—nine in all, as follows:

No. 1—Some minutes before totality (exact time not noted). Plate PASSAVANT'S C. I. P., exposure $\frac{1}{64}$ of a second, timed with a NEWMAN shutter.

No. 2—Not quite two minutes before totality (exact time not noted), as the counting had not commenced, but it did commence immediately after this exposure was made. Plate C. I. P., exposure $\frac{1}{16}$ second.

No. 3—The exposure of this commenced on the first second of totality and was of 3 seconds duration. Plate PASSAVANT'S H. L. of about 15 sensitometer register.

No. 4—Was exposed 4 seconds during the 20th to 24th seconds of totality. Same kind of plate as the last.

No. 5—Had 6 seconds between the 41st and 47th seconds of totality; also H. L. plate.

No. 6—Was exposed 1 second from the 60th to 61st seconds of totality; H. L. plate.

No. 7—Had only $\frac{1}{2}$ a second exposure at the 78th second of totality; H. L. plate.

No. 8—Had 1 second exposure from 91st to 92d seconds of totality, on H. L. plate.

No. 9—Was exposed a second or two after time was called at the 104th second; the exact time was not noted. This was on a C. I. P. plate.

My assistant, who recorded the time for me, was the Hon. FRANK C. DE LONG. No difficulty was experienced in developing the plates. Those taken during totality I treated as if under-exposed, and used two and three times the normal quantity of potash and soda.

I made no sketch of my optical observations, as I was too busy making exposures. I may state, however, that I saw the Corona 9 or 10 seconds before totality and somewhat longer afterwards.

I beg to draw your particular attention to negative No. 2 (the one with the clouds), as proof of what a narrow escape we had from having our observations ruined.

Yours respectfully,

WM. LETTS OLIVER.

SAN FRANCISCO, January 31, 1889.

Mr. CHARLES BURCKHALTER, *Chabot Observatory:*

DEAR SIR: Herewith I hand you my report of observations made at Cloverdale, January 1, 1889, and at San Francisco, January 15, 1889, to ascertain the comparative value of the strength of the actinic light during the Total Solar Eclipse of January 1, 1889, and that of the Moon twenty-five hours before full.

A plate registering 15, with WARNERKE'S sensitometer under ordinary test (luminous tablet, lighted up with one inch of magnesium wire, and after one minute's rest, exposure of 30 seconds) was cut into small plates, *a* and *b*.

Plate *a* was exposed by my assistant, THOMAS ANDREWS, in the same sensitometer, at Cloverdale, for exactly 15 seconds during the totality of the solar eclipse (January 1, 1889), viz., from 41 to 56 seconds of totality. This plate *a* was kept in the dark until January 16, when it was developed together with plate *b*.

Plate *b* was exposed at San Francisco, in the same sensitometer, on January 15, 1889, at 8:30 P. M. to the Moon, at which time she was at an altitude of about 22° (being the same as at the solar eclipse) for exactly 15 seconds. This was 25 hours before full Moon; the night was bright and clear.

Plates *a* and *b* were developed together in a pyro developer of normal strength (6 grains pyrogalot, 30 grains carbonate of potash, 42 drams water), for 4 minutes.

Before fixing

Plate *a* showed 23.
Plate *b* showed 10.

This indicates, according to WARNERKE's scale, that the actinic light during the solar eclipse was 36 times as strong as that of the Moon at the time above mentioned; or

Intensity of actinic light of full Moon—(25 hours)=1.
Intensity of actinic light, middle of solar eclipse=36.

I am well aware that this test can not be considered a definite one, but it may be regarded as a basis for future similar experiments.

It is a known fact that the scale of the WARNERKE sensitometer absorbs actinic light, on account of the pigment which is used in its manufacture; the more so in the higher numbers, where the pigment has very dark shades. Also, the shades of the different squares are not perfectly reliable in all instruments. The WARNERKE sensitometer is therefore not well adapted for comparing the intensity of light from different sources.

The future similar experiments, an instrument of the kind of VOGEL's tube photometer would give more reliable results. However, such a photometer was not at my disposal, and the time was too short to construct one.

Very truly yours,

DR. S. C. PASSAVANT.

SAN FRANCISCO, January 1, 1889.

Mr. CHAS. BURCKHALTER:

MY DEAR SIR: I desire to report to you as follows: In observing the Total Eclipse of the Sun to-day under your instructions, I used a 3½-inch telescope, WRAY objective, power about 30. I called the time of beginning and ending of totality and found its duration 104 seconds. My time exactly agreed with Mr. COMPTON's who sat next to me in the field—he observing with a sextant. There was no appearance of Baily's beads. The west limb of the Moon was comparatively clear, and obscuration clearly marked. But about three minutes before totality and before time was called (which was about 100 seconds before totality), I observed the

southern portion of the crescent of the Sun apparently split about two fifths of the distance towards the northern cusp.

Thinking this an optical illusion, I brought it to the centre and again to the side of the field, but still observed it distinctly. It was soon covered by the advancing Moon. I called the attention of Mr. COMPTON to it immediately after the totality, and he said he observed it also.

As the Moon's disc occupied almost the entire field of my telescope, I did not attempt to observe the Corona, lest in moving my glass laterally too far, I might lose the close of totality, to which duty you assigned me.

The chromosphere seemed to me quite uniform in appearance and I did not observe any marked solar protuberances.

I enclose a drawing of the Corona as observed by my son, LAUNCE H. PIERSON, with a pair of powerful marine glasses, and his report thereon.

Yours truly,

WM. M. PIERSON.

SAN FRANCISCO, February 1, 1889.

Mr. CHAS. BURCKHALTER, *in charge P. C. A. P. A. Expedition:*

SIR: I have the honor to send herewith four (4) 5x7 negatives made by me of the Solar Eclipse at Cloverdale, January 1, 1889. The negatives are all on PASSAVANT'S H. L. plates, having a sensitometer register of from 15 to 17.

The lens used was a DARLOT rapid hemispherical doublet of 8½-inch focus, having the front combination removed, giving a focus of about 17 inches.

The stop or diaphragm was F/8.

The development was made with pyro and potash.

Exposure as per card herewith, viz.:

Plate No. 1—Exposed 17 seconds, between the 3d and 20th seconds of totality.

Plate No. 2—Exposed 8 seconds, between the 40th and 48th seconds of totality.

Plate No. 3—Exposed 4 seconds, between the 81st and 85th seconds of totality.

Plate No. 4—Exposed 1 second, from the 101st to 102d second of totality.

My assistant was Mr. GEO. B. BAER, who did the work assigned to him with care and intelligence.

In conclusion, I must say that personally I saw little or nothing of the Corona, being so intent on exposing my plates properly that I gave my entire attention to them.

Yours very truly,

GEO. W. REED,

Vice-President Pacific Coast Amateur Photo. Asso.

SAN FRANCISCO, January 31, 1889.

Mr. CHAS. BURCKHALTER, *in charge of Cloverdale P. C. A. P. A. Observing Party:*

DEAR SIR: My business engagements being such that I could not take time to prepare any special apparatus, I either had to use one of my view cameras, with the rapid rectilinear lens belonging to it, or give up all idea of joining the photographic expedition. As this would have been a great disappointment to me, I concluded to accompany the association and do the best I could with a light, compact HARE (English) camera, $4\frac{3}{4}$x$6\frac{1}{2}$, fitted with sliding plate-holders, DALLMEYER $6\frac{1}{2}$x$8\frac{1}{2}$ rapid rectilinear lens, 11.30 in. equivalent focus.

On arriving on the field, I found that, owing to the projection of the focusing screw below the bed of my camera, a trestle and board which had been reserved for me, could not be used conveniently without nailing on several cleats. These not being available, I concluded to use my tripod, and it proved entirely satisfactory.

I followed the directions found in "Instructions for Observing the Total Eclipse of July, 1878," contained in the report issued by the U. S. Naval Observatory, and focused on the most distant object I could find, and then turned my camera so as to bring the image of the Sun in the middle of the plate, but a well known photographer who was looking on informed me that I was badly out of focus. Having considerable confidence in his judgment, I changed the position of my ground glass, but think I made a mistake in doing so, as I now strongly suspect I was in better focus before the change than afterwards—at any rate my image was much larger.

Being provided with comparatively slow plates (PASSAVANT'S H. L., sens. 17), I was detailed to give exposures of 10, 8, 6, etc., seconds, with the largest diaphragm F/8.684. This I did, but was much surprised, on developing the plates, to find the image to be

towards the lower righthand corner of the plates instead of in the centre where I carefully placed it before exposure. The change may and probably was caused by a jar of the camera, but, at the time, I was quite positive that it had remained rigid.

Having, of course, had no experience in developing negatives of this kind, I used the normal developer recommended by the maker of the plates, as appended below:

PYRO-DEVELOPER.

SOL. I.

Distilled water	8 ounces.
Sulphite soda	2 ounces.
Citric acid	60 grains.
Pyrogallic acid	1 ounce.

SOL. II.

Carbonate potash C P	8 ounces.
Sulphite soda	2 ounces.
Distilled water	16 ounces.

Water	5 ounces.
Sol. I	1 dram.
Sol. II	1 dram.

Although watching carefully for the Corona, I did not see it either before or after totality. Neither did I see any Sunflames at any stage of the eclipse. Just before totality, we were told to look for the shadow of the Moon approaching us from a southwesterly direction, but neither I nor those in my immediate vicinity observed it. This, I think, was owing to the fact that we were stationed in the center of a level field, and were looking towards some oak trees back of which was a ridge of low, rolling hills. While busy making the exposures, I glanced hurriedly at the Sun between times, being curious to see the streamers and colored flames which it was predicted would be visible. I was unable to make out either, the Corona appearing to be a simple fringe of light, of uniform width, surrounding the Moon's disc. Figure 1, Plate 24 (without the colors), in the report mentioned above, represents the eclipse exactly as it appeared to me.

The exposures were—

From 6th to 16th second; 10 sec.
From 40th to 48th second; 8 sec.
From 100th to 106th second; 6 sec.

Yours sincerely,

GEORGE TASHEIRA.

San Francisco, February 20, 1889.

Mr. Charles Burckhalter, *Chabot Observatory:*

Dear Sir: As you are aware, the enthusiasm of the members of the association has been roused by your description, in a lecture before them, of the work accomplished in astronomy by photography and the service that could be rendered eclipse-photography by ordinary apparatus used intelligently. The publication of further information in the press and by pamphlets regarding the eclipse kept up this interest, and twenty-four members volunteered assistance, to be made use of as you might direct.

As, with most of the photographers, my views of the eclipse were confined to the moments available when counting seconds of exposure, I saw neither Sunflames nor the shadow of the Moon traveling, though the transition from the last glint of sunlight to the partial darkness of totality was sudden, making the Corona appear to burst into view. I counted seventy seconds after the last call of time before the Corona disappeared. It appeared to me like a film of light behind the Sun's rays.

I had endeavored to attach my camera to a surveyor's transit, in order that the image might be of good size, but the weather just preceding January 1st prevented my making experiments on the Moon. This and lack of time prevented my finding the exact difference between the chemical and the visual focus. The transit was, however, taken to Cloverdale and used by Mr. Lewis Tasheira. The result of his observations are shown in the sketch marked "A," and as Mr. Tasheira is a civil engineer of note his findings are unusually worthy.

"The sketch was made immediately after the eclipse, though the general outline was sketched in during totality. My attention was mainly diverted to the colorless protuberances of light which projected beyond the inner Corona, as shown in my sketch. I saw no color in the Corona and observed no change in its outline during totality. It was visible to me sixty seconds after totality. The smoked glass held by Mr. Edes in front of the telescope was not of sufficient density to enable the eye to withstand the intense light; otherwise the Corona might have been observed a few seconds more. The instrument was an ordinary surveyor's transit. The image of the Moon nearly filled the field of its telescope so that the full extent of the outer Corona could not be seen."

Special effort was made by Mrs. LAURA B. ROE, Mrs. A. W. TRUESDELL, Miss SYLVIA REY, and Miss NELLIE L. TREAT, to secure sketches of the Corona, if possible, in color. The report of Mrs. ROE shows how difficult it is to do anything with colors in so short a time.

"It was my intention to procure a sketch in crayon showing the colors of the Corona, but the light was so dim and the time so short one could not select the proper crayons. I endeavored, therefore, to secure the luminous impression of the Corona with the colors at hand ("B"). The sketch made afterwards from memory ("C") is more correct in not showing any warm color in the Corona."

Miss SYLVIA REY's report shows the course followed by the sketchers, and the general color effects:

"As one of the party that observed the eclipse at Cloverdale, I made a drawing of the Corona as it appeared to me during totality. As the Sun's disc became more and more obscured, the landscape gradually assumed a peculiar appearance, much resembling, at its climax, the effect produced by an electric light. The sensation produced was the more weird and strange, accompanied as it was by a sudden fall in the temperature. For a short period preceding totality I closed my eyes in order to render them sensitive. They should, therefore, have been able to detect any colors which might have been visible in the Corona. The sky became a cold steel-blue. The Moon's disc did not appear black, and the Corona was a luminous pearl color, the radiations conveying to me the form given in my drawing ("D").

"I had prepared to make a color impression at the time, but I found my colors useless. Since then I have endeavored to reproduce in color some representation of what I saw, but it is impossible to give to the Corona that luminous silvery appearance, intense where it immediately surrounds the disc and dissolving into the color of the sky."

Miss TREAT corroborates the difficulties in the way of sketching in color:

"Through following instructions directing me to close my eyes a few minutes previous to totality, I lost some of the effect of the diminishing light upon the landscape. I noticed, however, immediately preceding obscuration, that the surrounding hills assumed a deep purplish hue. The atmosphere seemed to be of a greenish, metallic blue. I noticed also the extreme sharpness of the shadows of different objects.

The time available for sketching was so short I could only make the merest outline of the Corona and without detail ("E"). The inner Corona appeared to me of an intense luminous metallic blue. The streamers of the outer Corona were of an intense white light, well defined for a certain distance and then fading away into the surrounding atmosphere. Although I noticed no red or yellow light in the Corona I have since found, in trying to make a color sketch from memory ("F") that to produce the intensely luminous effect it is necessary to use the primary colors, red, blue, and yellow. I have found it impossible to reproduce by any method of coloring the intensely luminous appearance of the Corona. My color sketch is simply suggestive of the general effect."

When returning from Cloverdale in the afternoon of January first, I secured from these ladies, collectively, by questioning them individually, the following concensus of opinion.

The sky before totality was of a leaden blue color; during totality it became lighter and more luminous as it extended to the Corona, seeming to be illumined by its light. The light near the disc of the Moon was of an intense luminous silver, with a bluish tinge, similar to the light of an electric arc. The streamers of the outer Corona, extending in an oblique direction, were similar in color, though fainter, fading away into the surrounding sky. The disc of the Moon appeared of a dark hazy purple, assuming a gaseous, filmy aspect. At no time did it appear black. No warm colored rays of light were seen at any time.

Mr. C. Mason Kinne's remarks, accompanied as they are by an excellent sketch ("G") made while on the ground, are of value.

"The drawing as to diameter is as accurate as the eye and low objective can make it. Color of inner Corona, a cold, steely blue, fading into purple, red, and slight yellow. There was a slight protuberance on the northwest limb. A small, reddish, purple Sun-flame was seen near the north pole of the Sun."

I would also draw your attention to the sketch of Capt. C. L. Hooper, of the U. S. revenue cutter Corwin ("H"), also from observations through a telescope and made within five minutes after totality. The sketches of Mrs. A. W. Truesdell, W. C. Gibbs, and Dr. C. L. Goddard, conclude the number of trust-worthy drawings made by our party. All of them were taken up as soon after totality as practicable. In the case of the ladies, whose eyes were unaided, the drawings were untouched.

To those accustomed to sketching probably better work could be accomplished by devoting the short time of totality to close observation, immediately afterwards, and without comparison of notes making a detailed sketch of their impressions.

I exposed successfully six plates, all of them are forwarded herewith. I note that an exposure of 6 seconds on a PASSAVANT plate of 17 sensitometer (Plate No. 4), appears identical with a 6-second exposure on a CARBUTT eclipse of 27 sensitometer. No. 3 was developed with a solution strong in pyro; the inner Corona was brought up to sufficient density before the outer had fairly started. The other negatives were developed with a diluted developer weak in pyro, and this seems the correct one for saving the delicate half tones of the outer Corona.

I used an ordinary camera mounted on a trestle for steadiness. Lens, DARLOT's Rapid Hemispherical No. 3; stop F/40.

Plate No. 1—1 to ½, exposure 5 seconds.
Plate No. 2—16 to 24, exposure 8 seconds.
Plate No. 3—39 to 42, exposure 3 seconds.
Plate No. 4—55 to 61, exposure 6 seconds.
Plate No. 5—74 to 76, exposure 2 seconds.
Plate No. 6—88 to 96, exposure 8 seconds.

Mr. W. N. McCARTHY was my recording assistant.

The association is indebted to Messrs. BRITTON and REY for the lithographed sketch cards kindly contributed by them and which were distributed among the party. The tally cards used for recording the photographic exposures were presented by Mr. J. V. A. REY.

In conclusion, let me congratulate you upon the success of your arrangements. There was nothing lacking for our comfort during our stay at Cloverdale, and not the slightest hitch occurred to mar the perfect success of your carefully prepared programme.

Very respectfully yours,

A. J. TREAT,
President P. C. A. P. A.

SAN FRANCISCO, February 1, 1889.

Mr. CHARLES BURCKHALTER, *Chabot Observatory, Oakland:*

DEAR SIR: Herewith I beg to submit to you my contribution for your report on the Eclipse Expedition to Cloverdale.

As my eyes were not protected, and employed in adjusting the camera from time to time, I was not in a condition to make any

observations of the Corona with the eye; in fact, it appeared to me simply as two overlapping rings of light.

Recording assistant, E. B. Moore.

Plates exposed successfully: Three before totality, eight during totality, and three after totality. Those exposed during totality are:

No. 1 from (?)th to 16th second—7 seconds.
No. 2 from 24th to 27th second—4 seconds.
No. 3 from 36th to 42d second—7 seconds.
No. 4 from 53d to 57th second—5 seconds.
No. 5 from 69th to 71st second—3 seconds.
No. 6 from 81st to 90th second—10 seconds.
No. 7 from 96th to 97th second—2 seconds.
No. 8 from 105th to 106th second—2 seconds.

The above exposures are from the record, but think that they all represent rather longer exposures than were actually given, as the shutter used worked quicker than the voice.

I hand you herewith three pieces of Eastman film representing phases before totality. In one of these (though over exposed) the Corona appears to show two glass positives representing negatives Nos. 2 and 3.

On the negatives *Mercury* is distinct, but not strong enough to print. I have already handed you two plates containing four negatives each, being Nos. 4 to 8, as above, and three exposures made after totality; the number 8 appears to have been made at the moment when the Sun began to reappear.

Description of apparatus:

All my exposures were made on Eastman films, and the two large plates containing eight negatives are therefore reversed; *i. e.*, the real face of the negative is against the glass. The camera used was of home-made construction—a box 16 inches long, supported on a baseboard, hinged at the rear, and with adjustable struts for elevating the front. Fitted with a Green shutter, opening on the pressure of the bulb, and closing on the release of the pressure. Lens used was back half of a Dallmeyer type of Rectilinear, with stop F/16, focal length about 16 inches. All negatives made on Eastman's extra quick stripping films, exposed in a roll holder of same firm. Developed with hydroquinone and soda carbonate, weak.

Yours respectfully,

Edm. L. Woods,
Member of P. C. A. P. A.

NOTES ON THE NEGATIVES DEPOSITED AT THE LICK OBSERVATORY BY THE MEMBERS OF THE PACIFIC COAST AMATEUR PHOTOGRAPHIC ASSOCIATION.

By JAMES E. KEELER.

The negatives obtained by the members of the Pacific Coast Amateur Photographic Association were sent to the Lick Observatory, and are kept there for reference.* They have been used by Professor HOLDEN in preparing his description and diagram of the Corona, and by myself in studying the forms of the outer coronal streamers. The full value of the work of the Association can only be obtained by a comparison of the reports of its members with the original negatives, but as this will not be possible for most of those who are interested in the subject, I have prepared a description of the negatives in order to make the results as far as possible available to others than ourselves. In all questions involving photographic methods, I have sought the advice of Mr. BARNARD and Mr. BURNHAM.

It will be seen, on reference to the report of Mr. BURCKHALTER, that the work of the Association was arranged to produce the most valuable results of its members as a body, and that each observer was not occupied in the comparatively simple process of endeavoring to get the best possible general view of the eclipse. In fact, the special work allotted to some of the observers made a satisfactory picture impossible. Under this arrangement a failure to secure any given feature is as instructive and important as a success.

Negatives by Chas. Burckhalter.

The beautiful negatives of Mr. BURCKHALTER require little comment, as they have been partially described by himself and by Professor HOLDEN. An attempt was made to reproduce his negative No. 9 by a photolithographic process, but the result lacked so much of doing justice to the negative that the attempt was abandoned. In No. 3 the outlying wings of the Corona on the west extend as far as 48′ or 50′ from the Moon's centre. This is also the best general view of the Corona. No. 6 is very dense in the inner Corona, but does not have the same extent as No. 3.

* Or returned on the request of the owners.

The prominences are particularly well shown in No. 5 and No. 11. In the former they are a little over-exposed.

In No. 5 the polar rays are shown very nearly to the Moon's limb. The greatest extent of the Corona on this plate is 35′ from the centre.

No. 11 is a very interesting plate. The exposure ended at the instant of third contact, and the reappearing photosphere has produced an aureole around the point of contact, due to total reflection at the back of the plate. That the contact had just occurred, is shown by the circular shape of the aureole and the excellent definition of the chromosphere above the point, close to which is a large prominence with a detached portion floating near its summit (the same prominence as drawn by Mr. Brashear). The entire depth of the chromosphere is therefore shown at the point of contact. Placing the plate on the measuring engine of the Lick Observatory, I made the following measurements:

Diameter of Moon's image	=0.7760in=	2000″=——	miles.
Outer edge of chromosphere above limb of Moon	=0.0106 =	27.3	=12,100 miles.
Summit of prominence above limb of Moon	=0.0260 =	67.0	=29,700 miles.
Outer point of detached portion above limb of Moon	=0.0326 =	84.0	=37,200 miles.

The heights are probably somewhat too great, on account of a slight solarization of the limb of the Moon.

The diameter of the image of the Moon in Mr. Burckhalter's negatives (0.78 inches) is greater than in any others which have been sent to the Observatory.

Negatives by George W. Dornin.

Mr. Dornin has contributed four negatives.

No. 1 shows the coronal streamers extending 40′ from the Moon's centre. There is very little detail.

No. 2, an instantaneous exposure, shows merely the inner Corona, as a ring about 4′ wide. The camera appears to have been jarred in exposing, as the prominences have left short trails in a nearly vertical direction.

No. 3, exposed 10 seconds, shows the trumpet-like extension of the western streamers pointed out by Professor Holden in figure 1. They can be traced to 90′ from the Moon's centre. *Mercury* appears as a strong black dot.

No. 5 was still exposed at the end of totality and has somewhat the same appearance as Mr. Burckhalter's No. 11. The expos-

ure was however continued longer, and the Corona on the side of the reappearing Sun is nearly obliterated.

Mercury can be seen on this plate also.

These plates do not show the polar rays separately. Either the focus was not perfectly sharp, or the camera was vibrating slightly. The latter appears to be the more probable explanation, as an ordinary light tripod was used.

Negatives by W. C. Gibbs.

Both of the negatives by Mr. Gibbs were made with a small aperture and short exposure, as will be seen by referring to his report. They are remarkable for the excellence of definition. The polar rays are particularly well shown in No. 2, the more sensitive plate, in which also the extent of the Corona is greatest, the western streamers extending 26′ from the Moon's centre.

Negatives by Clark L. Goddard.

No. 1 shows the inner Corona, extending 25′ from the Moon's centre, on the west side. At the poles the beginnings of the brushes of light are shown, but not very distinctly.

No. 2. Polar rays not shown separately. Greatest extension of Corona 45′ from the Moon's centre.

No. 3. Best general view. Polar rays not shown separately. *Mercury* appears as a sharp black trail nearly 3′ long. The greatest extension of the Corona is 50′ from the Moon's centre.

No. 5 is much like No. 2, except that the Sun appeared during the exposure. The coronal outlines can still be seen. *Mercury* is not certainly shown.

Negatives by C. P. Grimwood.

These negatives are somewhat alike, all having been made with long exposures.

No. 1. The greatest extension of the Corona is 55′ from the Moon's centre. The polar rays are indistinctly shown.

No. 2. The Corona extends 60′ toward the west. Polar rays not separately shown.

No. 4. Much like No. 2.

No. 5 shows the greatest extension of the Corona, 62′ from the Moon's centre. Polar rays not shown.

No. 6. The sun reappeared during the exposure, but the coronal outlines persist. The polar rays are very indistinctly shown.

Mercury appears as a short black trail on all these plates.

Negatives by James H. Johnson.

No. 1 is a good general view of the Corona. The polar rays are indistinctly shown.

No. 2 is very sharp and distinct—probably as good a picture as could be obtained with so small an image. The greatest extent of the Corona is 40′.

No. 3 is like No. 2, but is not so sharp.

No. 4 is much like No. 1, but the density of the image is less.

No. 5 is a good general view, and shows a considerable extension of the Corona (55′). The polar rays are shown, although blurred by the motion of the image.

No. 6 shows the greatest extension of the Corona (60′). The polar rays are not separately shown.

No. 7 is sharp, and much like No. 5.

No. 8 was caught by the returning sunlight, and the camera was badly jarred. It shows but little.

Mercury appears on all the plates but the last.

In transmitting these negatives to the Lick Observatory, Mr. Johnson called attention to the fact that three of the plates (Nos. 3, 6, and 7), show specks in position angle about 225°, which coincide when the plates are superposed, and that it was possible that these might be photographic images of some unknown object near the Sun. The distance of the speck from the Moon's centre is about 50′.

The plates were therefore carefully examined by Professor Holden, Mr. Barnard, and myself, and compared with other negatives. The conclusion which we reached was, that the specks were accidental, for the reasons briefly stated below:

1. The speck on Plate No. 3 under a magnifying glass does not present the appearance of a photographic image.

2. The distances of the specks from the Moon's centre, although in close agreement, differ too much for photographic images of a real object.

3. The speck does not appear on Plate No. 5, although *Mercury* is well shown, and this plate is quite free from accidental specks and blemishes.

4. The speck does not appear on the negatives of Messrs. Burckhalter, Ireland, Lange, and Lowden.

5. There is no corresponding speck on Mr. Barnard's Plate C, although this is the only plate in our possession which shows the star σ *Sagittarii.*

Negatives by O. V. Lange.

The four negatives sent by Mr. LANGE are more alike than the considerable differences in the exposures might lead one to expect, probably because the short exposures were made on quick plates and the long exposures on slow ones.

No. 1 is the best general view. Greatest extent of Corona, 55′. The polar rays are fairly well shown.

No. 2 shows the greatest extent of the Corona, 60′ from the Moon's centre. The outer ends of the polar rays can be separately distinguished.

No. 4 is much like No. 1.

No. 5 was caught by the returning sunlight. The outlines of the Corona remain the same, where they are not obliterated by the fogged circle around the point of reappearance. The polar rays are well shown.

The focus in these negatives appears to be very sharp. *Mercury* shows in all the plates as a very small and nearly round point.

Negatives by William H. Lowden.

The negatives of MR. LOWDEN have been fully discussed by PROFESSOR HOLDEN in the introduction, and it is unnecessary to repeat the description here.

Negatives by C. F. Montealegre.

The original negatives were not sent to the Lick Observatory. Of the two positives sent, No. 1 shows the Corona extending 45′ from the Moon's centre, and No. 2 shows the Corona as far as 75′. The motion of the image was considerable and little detail appears. *Mercury* is beyond the limits of the plate, in both positives.

Negatives by William Letts Oliver.

These have not been sent to the Lick Observatory.

Negatives by Dr. S. C. Passavant.

The plates exposed by Dr. PASSAVANT for obtaining a measure of the actinic value of the light of the Corona and sky during totality have been described in his report. Two negatives of the Corona which were also made are not there described.

Plate No. 1 (PASSAVANT C. I. P.) was made with a STEINHEIL aplanatic lens of 11.2 inches focus, and a stop reducing the aperture to F/8. The exposure was about $\frac{1}{30}$ second at the 7th second

of totality. The inner Corona is shown as a ring of light 3′ in breadth at the poles and a little greater at the equator. The camera was vibrating a little at the time of exposure as the prominences have left short trails.

Plate No. 2 (Passavant C. I. P.) was made with the same apparatus, but with 4 seconds exposure, from the 64th to the 68th second of totality. It is a good general representation of the Corona, notwithstanding the small size of the image, but the polar rays are obliterated by the motion during exposure. The greatest extent of the Corona is 80′ from the Moon's centre.

The outlines of distant trees are very distinctly shown on the same plate, and also the clouds near the horizon, where the actinic effect is much greater than in the sky near the Corona.

Negatives by George W. Reed.

No. 1 shows but a small extension of the Corona, notwithstanding its long exposure, probably because the development was not continued long enough for that purpose.

No. 2 resembles No. 1, but shows the details more distinctly. The extent of the Corona is somewhat greater.

No. 3 is like No. 2.

No. 4 shows the smallest extension of the Corona. The polar rays are not separately shown. *Mercury* appears on all the plates.

Negatives by George Tasheira.

The negatives of Mr. Tasheira are much out of focus, probably for the reason given in his report.

Negatives by A. J. Treat.

Plate No. 1 shows polar rays fairly. Corona extends 45′ from the Moon's centre.

No. 2—Excellent general view.

No. 3—Shows but little.

No. 4—Much like No. 1.

No. 5—Best general view. Much like No. 2. This plate shows the greatest extension of the Corona, 60′ from the Moon's centre.

No. 6—Is much like No. 1.

Mercury is shown on all of these plates. Trees in the landscape are shown in all except No. 3.

Negatives by E. L. Woods.

The negatives made by Mr. Woods during totality are fair general views, showing indistinctly the polar rays.

Two plates exposed before totality show the entire outline of the Moon on the background of the Corona. One of these was made but a few seconds before second contact, the other much earlier. Unfortunately the time was not recorded, so that it is not definitely known when the plate was exposed. Mr. Woods thinks it was made some time during the count, that is, at less than 52 seconds before totality. From the measured distance between the cusps of the solar crescent I have computed the time before second contact to be 72 seconds, but the "solarization," or spreading of the photographic image, makes this method inaccurate. It will be seen, on reference to Mr. Burckhalter's report, that at 70 or 80 seconds before totality the Sun was clouded, and it was not until about half a minute before totality that the clouds passed away. Mr. Woods' negative shows light clouds just clear of the east limb of the Moon, and from this I have concluded that the exposure was made 30 seconds before totality, or possibly a little earlier.

After examining these and other photographs of the eclipse in the possession of the Lick Observatory, it seems to me that the following general conclusions may be drawn:

1. On account of the granulations in the plates, but little detail can be expected in a photograph of the Corona, in which the image of the Moon is less than a quarter of an inch in diameter, no matter how carefully the focus may be adjusted. In the future, if the object is to secure a representation of the more delicate coronal details, cameras should be employed in which the diameter of the Moon's image is half an inch or more, this implying a focal length of at least 54 inches. If only the general form, or the greatest extent of the Corona, or a measure of the brightness of large areas of sky is desired, small cameras may be used to advantage.

2. With the average lenses and plates used during the recent eclipse, the "instantaneous" exposures show only a narrow ring of the inner Corona. In order to give an idea of the exposure required for a satisfactory picture, I have selected a number of negatives which give the best general view of the Corona, and tabulated the corresponding data below. By best general view I mean that one which most satisfactorily represents the appear-

ance and details of the Corona as a whole, so that it would be retained if it were necessary to dispense with all the plates but one.

The fifth column gives the actual length of exposure, and the sixth column the exposure reduced to an aperture of one fifteenth of the focal length, which is the usual ratio in achromatic telescopes. No attempt has been made to introduce a correction for the sensitiveness of the plates, as the sensitometer tests of different makers are not uniform.

NEGATIVE.	Focus.	$\frac{a}{f}$.	Plate.	Exposure.	Reduced to $\frac{f}{15}$	Remarks.
	in.			*s.*	*s.*	
E. E. Barnard, No. C..	48.6	27.9	Seed, No. 26	4.5	1.3	
Charles Burckhalter, No. 3	84.0	8.0	Passavant C. I. P., No. 23	2.0	7.0	Reflector.
Charles Burckhalter, No. 9	84.0	8.0	Passavant H. L., No. 15	5.0	18.0	Reflector.
L. Hutchinson, No. 6.	31.0	13.8	Cramer's Lightning, No. 30	12.0	14.0	
Jas. H. Johnson, No. 2.	14.0	16.0	Passavant C. I. P., No. 23	3.0	2.6	
O. V. Lange, No. 1	12.5	16.0	Passavant C. I. P., No. 23	0.25	0.2	
Emmet Rixford, No. 4	25.0	12.5	Cramer's Lightning, No. 40	2.0	2.9	
A. J. Treat, No. 5	12.0	40.0	Carbutt's Eclipse, No. 27	2.0	0.3	

It will be seen that the reduced exposures vary greatly, owing, probably, to different methods of treatment in developing, or to differences in the transparency of the atmosphere at the places where the photographs were taken. On some of the plates the images are so small that it is difficult to form any correct judgment as to the character of the picture. With the larger apparatus the best general results were obtained with an exposure of several seconds. Longer exposures show a greater extension of the faint outlying streamers, but no more of the Corona within the 50′ circle.

3. The best negatives of the Corona in the possession of the Lick Observatory show details near the poles of the Sun whose width is only $\frac{1}{100}$ of the diameter of the image of the Moon, or about 20″—for instance, faint polar rays of this width alternating with darker spaces. These details would be obliterated by a motion of the image equal to this amount, which would require $1\frac{1}{3}$ seconds of time, if the camera were fixed. As the exposure

required for the impression on the plate is longer than this, it follows that with the dry plates ordinarily in use an equatorial mounting with clockwork is necessary in order to produce the best results. Many negatives in the possession of the Observatory show the truth of this. They would have been very satisfactory if the image had been kept in position.

4. The polar rays were at about the limit of perception with the naked eye. They are shown in sketches by some good observers, and not by others. They were noticed by nearly all who had the slightest optical assistance.

James E. Keeler.

PART IV. ABSTRACTS BY MR. J. E. KEELER OF THE MISCELLANEOUS OBSERVATIONS COMMUNICATED TO THE LICK OBSERVATORY.

[ARRANGED ALPHABETICALLY BY TOWNS.]

ALAMEDA, ALAMEDA COUNTY, CALIFORNIA.

F. R. ZIEL, Observer.

The phases of the partial eclipse were photographed by exposing at regular intervals 15 minutes, the camera remaining fixed in position. Eleven views of the Sun are thus shown on the same plate.

ANTIOCH, CONTRA COSTA COUNTY, CALIFORNIA.

WM. WIGGIN SMITH, Observer.

The colors of the sky and landscape were noted during the partial eclipse.

BARTLETT SPRINGS, LAKE COUNTY, CALIFORNIA.

P. MCGEE, Observer.

A sketch of the Corona as seen with the naked eye was made during totality, showing fish-tail streamers extending about $1\frac{1}{2}$ diameters from the Sun toward the east, and west, and position of prominences. The Corona is described as being brighter east of the Moon during the first third of totality, and brighter on the west side during the last third. The inner Corona was somewhat brighter than the full Moon in a clear sky, and extended from $\frac{1}{12}$ to $\frac{1}{15}$ of the radius of the Moon outward.

The duration of totality by watch was $1^m\ 54^s$.

BARTLETT SPRINGS, LAKE COUNTY, CALIFORNIA.

MRS. C. B. HILL, Observer.

A sketch of the Corona as seen with the naked eye was made during totality, showing the fish-tail equatorial streamers and the polar rays.

Bartlett Springs, Lake County, California.

Frederick Klays, Observer.

A sketch of the Corona was made during totality, with the naked eye. The general outlines of the streamers are very nearly as in the photographs. On the west, the streamers extend three diameters from the Sun. No polar rays are shown.

Bartlett Springs, Lake County, California.

F. B. Staples, Observer.

The Corona was observed with the naked eye while turning the photometer wheel for Mr. Leuschner, of the Lick Observatory party, and a sketch made from memory immediately after totality. It shows the fish-tail streamers extending a little more than 1½ diameters from the limb of the Moon. The polar rays are not separately shown.

Bartlett Springs, Lake County, California.

George W. Yount, Observer.

An oil sketch of the Corona was made during totality, and another with corrections immediately afterward. The fish-tail streamers and the polar rays are well shown, the greatest extension of the former being nearly two diameters of the Moon toward the west. The northeastern streamer is the shortest, and is straight and narrow, as in the photographs.

The background (previously prepared) on which the first sketch was made, is of a yellowish brown color, like that of the plates in the *Report of the Total Eclipse of July 29, 1878*, by the U. S. Naval Observatory. In the corrected sketch it is a dull leaden blue, and the Corona has a slightly yellowish tinge. The outlines of the Corona are in remarkable agreement with the photographs.

The observer has had much experience in rapid oil sketching.

Berkeley, Alameda County, California.

E. M. Hilgard, Observer.

Shadow bands were observed near the time of greatest obscuration (about $\frac{11}{12}$) for one and a quarter minutes. The width of the dark band was about one inch, and the distance between them

from 7 to 9 inches. Between the prominent dark bands were fainter or secondary lines from $\frac{1}{4}$ to $\frac{1}{2}$ inch in breadth. They ran from east to west, somewhat faster than a man could run, and vanished quite suddenly at 1^h 49^m $14\frac{1}{4}^s$ Standard Pacific Time.

These bands resembled the heat waves rising from a prairie plain on a hot day.

Berkeley, Alameda County, California.

By Prof. Frank Soulé.

It was the intention at this Observatory to get the times of first and last contact of the Moon with the Sun as accurately as possible, using the $6\frac{1}{4}^{in}$ equatorial telescope to throw with a power of seventy-five diameters the images on a fine white paper screen. Also to observe general atmospheric and meteorological phenomena.

The sky was little obscured by clouds at sunrise, and those were of a rather light, fleecy nature. A cool wind was blowing from the north, promising clear weather. But as noon drew near heavy cirro-cumulus clouds came up from the southeast and covered the Sun. This was a flock-wool sort of cloud, with dark patches and lighter ones intervening. Occasionally the Sun would break through and show quite a sharp image, but a portion of cloud a little denser than the average covered its face at first contact and we were only able to place it at between 24 and 25 minutes after 12, Pacific time. If the cloud spot had been put on intentionally, it could not have been better timed to cause the loss of first contact.

Shortly after first contact the sky cleared somewhat, although a bright haze still was surrounding the Sun. The sky gradually took a sombre tint, which at maximum obscuration resembled the light of an autumn sunset. Vapors condensed in the air and the temperature fell rapidly. The clouds near the zenith remained white in color, but those near the horizon, particularly in the west and southwest, under the Sun, had a pale rose tint. The new green grass looked very yellow, approaching toward a russet tint, and the trees and foliage had a dark, sombre hue. The illumination at time of greatest obscurity was like that from a very powerful, wide-spreading electric light.

For about 8 minutes, at the middle of the eclipse, the delicate shadow bands, resembling heat waves in the atmosphere, were

seen running along the ground from south to north, the undulations in each wave being from east to west. The breadth of each wave from north to south, as marked on the ground near the Observatory and on the south wall of that building, was about 6 to 8 inches. They were very noticeable, and generally remarked by numerous spectators standing near the Observatory.

The chill in the air became very great, and a breeze from the north sprang up.

As the afternoon wore on, the large clouds around the Sun seemed to be dissipated, and the fourth contact was easily and accurately obtained as 3 hours, 8 minutes, 54 seconds, Pacific time. The sky was, however, somewhat hazy, and became more so toward sunset.

A standard thermometer, carefully shielded from direct sunlight in a box with a curtain, showed that the temperature of the air fell from 65.5° at 12:24 P. M., to 49° at 2 P. M., and then rose rapidly to 57° at 2:44, showing a rapid reduction of air temperature by interposition of the Moon.

I could not see the Moon just before first nor just after the last contact, even with the sun-prism inserted in the equatorial and a light blue glass slide over the eyepiece.

By a cap the aperture of the telescope had been reduced to three inches.

Out-door Thermometer.

Number.	Time.	Reading.
1	$12^h\ 10^m$	65.5 Fah.
2	12 24	65.5
3	12 40	66.5
4	12 55	66.5
5	1 10	65.9
6	1 25	58.3
7	1 40	55.0
8	1 54	51.0
9	2 0	49.0
10	2 44	57.0
11	2 55	57.0
12	3 10	58.3

Read by Carl Rabe, with the exception of No. 10, which was read by me.

Wet-bulb Thermometer. No. 325. Green, N. Y.

Number.	Time.	Reading.
1	12h 10m	47.0 Fah.
2	12 25	46.5
3	12 41	46.5
4	12 56	47.0
5	1 11	47.4
6	1 26	46.9
7	1 41	47.0
8	1 55	46.0
9	2 50	45.75
10	2 55	46.5
11	3 10	46.0

Same reader, except No. 9, read by me.

Dry-bulb Thermometer. No. 272. Green, N. Y.

Number.	Time.	Reading.
1	12h 12m	55.9 Fah.
2	12 25	56.0
3	12 41	55.9
4	12 56	56.0
5	1 11	56.2
6	1 26	51.0
7	1 41	50.8
8	1 55	50.0
9	2 50	49.75
10	2 56	50.0
11	3 11	50.5

Same observers as in preceding cases.

The drawing on the right is a tracing of the record of the Draper thermograph of the older type, which was exposed to the direct action of sunlight during the whole day. The o'clock must be diminished by 35 minutes, as the clock and dial were too fast by that amount. [Sketch omitted.]

In case the matter is of interest to you, I can send the dial sheet down to you by mail.

The dial on the *new* thermograph in the louvre-box showed a small progressive diminution of temperature during the eclipse. This dial I can also loan to you, if you desire it.

Caspar, Mendocino County, California.

H. B. Phillips, Observer.

Two negatives were obtained during totality, with a No. 3, D. Dallmeyer lens, $2\frac{1}{8}$ inches in diameter, stopped down to $\frac{15}{16}$ inches, and having a back focus of $10\frac{1}{2}$ inches. The plates used were

PASSAVANT "H. L.," or ordinary slow plates. The first exposure was about 12 seconds, the other, 32 seconds. A shift of wind just before totality carried the condensed steam from a sawmill 300 yards distant, across the face of the Sun, which probably accounts for the entire absence of the outer Corona in the negatives, notwithstanding the long exposures. The same thing would also be produced by insufficient development.

The trails of the prominences are very distinctly shown.

CHICO, BUTTE COUNTY, CALIFORNIA.

O. W. JASPER, United States Deputy Surveyor, Observer.

Positions of prominences were observed during totality with a HELLER & BRIGHTLY transit, and drawings, with descriptions, were sent to the Lick Observatory.

CLOVERDALE, SONOMA COUNTY, CALIFORNIA.

CHAS. M. BAKEWELL, Observer.

Observations of Extreme Outer Corona, Eclipse January 1, 1889.

Place of observation, hill one half mile northeast of Cloverdale Station, Cloverdale, Cal.

Instruments, ordinary field glass, and black disc, with projections at intervals of 60°, fastened to an 8-ft. pole.

Distance from eye to disc, 5 ft. 5 in.

Size of disc, 1.56 in.

∴ aug. diam. of disc is 82′+ or more than 2½ times diam. of Sun.

Consequently, in addition to the inner Corona, the more apparent wings and streamers of the outer Corona were effectually obscured. When "time" was called, the cloth which had been placed over my eyes 5 minutes before, was removed with my eyes in position, so that the rays from the brighter portion did not strike them at all; so that they were exceedingly sensitive and ready to receive impressions of the extreme parts of the outer Corona, if such there might be, though very faint. During about the first half of totality, I could discern nothing but a very faint glow extending uniformly in all directions an indefinite distance from the Sun. But just as I was despairing of seeing anything,

and regretting that I had not been content to view the "glories of the eclipse" like any lay observer, there appeared, very indistinctly at first, a quadrilateral figure surrounding the Sun (or, more properly speaking, surrounding the projection of the black disc on the Sun and its surroundings). It was somewhat rounded on the top and bottom, and here extended about $\frac{2}{3}$ the diam. of the disc beyond the disc's edge. To the east and west it extended considerably further, to about one diam. of the disc, and here it tapered into decided points. During the remainder of totality, this faint illumination appeared to grow brighter and was more easily distinguished from the surrounding region, until it presented a decided clear cut image, as seen in the accompanying figure.* The color of this image was a very faint milky white. It was entirely uniform, not striated nor crossed by any lines, and not perceptibly brighter near the limb than at the circumference. The sky outside the image was not a pure blue, but faintly tinged with white.

The uniformity of this appearance would seem to intimate that it continued in toward the Sun, and formed a background to the brighter parts of the Corona. The fact that it was not observed by the observers of the brighter Corona would not vitiate this conclusion, because its *comparative* faintness would render it invisible. This, as well as its general outline, and the fact that it is apparently an addition to the Corona, would seem to indicate that it was the reflection of the Corona on some intermediate substance, or possibly on some filmy, almost invisible mist in front of the Sun. If this latter be the true explanation it would form an excellent proof that the Corona is a solar appendage, *i. e.*, is not due to our atmosphere, had this question not been already settled beyond a doubt.

But the fact that on this image there were no lines, nor roughnesses, nor anything more than the mere general outline corresponding to the brighter Corona, would seem to indicate that this fainter appearance, too, was due to some solar matter.

Charles M. Bakewell,
Class of 1889, College of Letters, University of California.

* Omitted.

Note on Mr. Bakewell's Observation.

The faint illumination which was seen outside the disc used to screen the Sun was probably as Mr. BAKEWELL concludes, due to the presence of reflecting particles between the Sun and the point of observation. These particles might, however, have been in our own atmosphere, that is, the appearance might have been due to haze. It would not be noticed by other observers for the reason given by Mr. BAKEWELL. The boundaries of the quadrilateral figure around the disc are roughly equally distant from the nearest bright portions of the Corona, and this fact is in favor of the above explanation. It is of course possible that the appearance was caused by particles in space around the Sun.

The outlying streamers of the Corona should have been visible beyond the limits of the disc.

CLOVERDALE, CALIFORNIA.

F. H. CARSSOW, Observer.

A drawing of the Corona was made with the aid of a 19-inch Y level by JOHN ROACH. It shows the fish-tail equatorial streamers, the polar rays, and the principal prominences; also, a large streamer occupying the position of rays 96 to 103 of the Index diagram, Figure 1, which does not appear in the photographs.

CLOVERDALE, CALIFORNIA.

WALTER M. CARY, Observer.

A naked-eye sketch of the Corona was made, showing the general outline.

CLOVERDALE, CALIFORNIA.

DR. G. GERLACH, Observer.

A naked-eye sketch of the Corona was made, showing somewhat convergent fish-tail streamers extending about one diameter on each side of the Sun. The color of the Corona in general is given as white.

CLOVERDALE, CALIFORNIA.

W. C. GIBBS, Observer.

A sketch of the Corona was made from memory after the eclipse, showing a general extension in the plane of the ecliptic.

CLOVERDALE, CALIFORNIA.

Dr. C. L. GODDARD, Observer.

A naked-eye sketch of the Corona was made from memory after the eclipse, showing a general equatorial extension.

CLOVERDALE, CALIFORNIA.

Capt. C. L. HOOPER, U. S. R. M., Observer.

The Corona was viewed with a small telescope, and a sketch made from memory after totality. It shows the fish-tail equatorial streamers extending about $1\frac{1}{2}$ diameters from the Sun.

CLOVERDALE, CALIFORNIA.

LINCOLN HUTCHINSON, J. S. HUTCHINSON, E. C. HUTCHINSON, M. R. DEMPTSER, R. R. DEMPSTER, W. Y. KELLOGG, Observers.

Report of Mr. Lincoln Hutchinson.

SAN FRANCISCO, January 15, 1889.

Prof. E. S. HOLDEN, *Director Lick Observatory, Mt. Hamilton:*

DEAR SIR: In accordance with the general request contained in the pamphlet issued from your Observatory in regard to the Total Solar Eclipse of January 1st, a party of eight or ten was organized about one month ago to make a few amateur observations of that eclipse. Our point of observation, which was chosen several days in advance, was on what is known as "Bald Mountain," about two miles in a direct line, and twelve degrees west of south (not allowing for the variation of the compass) from the town of Cloverdale. Our elevation, by barometric measurement, was about 1,000 feet above Cloverdale, and 1,300 feet above the sea. The day of the eclipse was clear and calm. In the valley there was quite a perceptible mist, but as our greater elevation

raised us above it, there was nothing to interfere with our view of the eclipse. There were a few light clouds in the atmosphere, but apparently there were none between us and the Sun.

We send you herewith our separate reports of the observations taken, together with our photographic negatives and the rough notes and sketches made during the period of totality. We did not attempt to take any observations during the partial phases of the eclipse.

Report on the Photographs.

Lens: A 2¼-inch acromatic lens, taken from an ordinary spy-glass, and having a focal length of about 31 inches. The outer surface of the glass was covered by a black card-board diaphragm, having a round hole in the center about eight-tenths of an inch in diameter.

Camera: A Blair "Tourograph" camera, with an extension in front to accommodate the focal length of the lens.

Plates: Cramer's lightning gelatine plates, sensitometer 30 (5″x7″), carefully marked to distinguish the top from the bottom, and numbered as in the accompanying schedule.

The camera was mounted on a wooden tripod, and firmly propped to prevent shaking.

By numerous experiments in photographing the Moon and light clouds, and a study of the suggestions contained in the Lick Observatory pamphlet, and in the United States Naval Observatory Report of the Eclipse of 1878, a series of exposures was decided on, ranging from the quickest possible hand-exposure to 20 seconds, and a programme was settled upon and adhered to on the day of the eclipse. The exposures were made by lifting a black curtain which hung in front of the lens, and were timed by the seconds-hand of a watch, a lighted lantern being used so as to see the watch dial distinctly.

The strips of paper pasted on the negatives show the top of the plate *as it was exposed*, and the accompanying schedule gives the details of the exposures, developments, etc. The plates were developed by James S. Hutchinson, special attention being given to bringing out the details of the outer Corona.

James S. Hutchinson,
Lincoln Hutchinson, U. C., '89.

P. S.—Just before the commencement of totality I watched carefully to see the shadow of the Moon passing over the mountains, but was unable to see anything of the kind; but just after the close of totality, I saw distinctly numerous diffraction bands passing very rapidly over the ground and giving it a wavy appearance. The bands were perhaps two feet apart, were very narrow, and passed in a direction from west southwest to east northeast.

In accordance with a suggestion in the U. S. Naval Observatory directions for observing the eclipse of 1878, the following instrument was prepared and placed in charge of WALTER Y. KELLOGG: a straight stick was divided by prominent lines into inches, and these were numbered from the centre of the stick towards both ends. A string exactly eighteen inches long was tied to the centre of the stick, and the other end was knotted, so as to be held conveniently between the teeth. This knot was held between the teeth, and the string stretched tight, the stick being held perpendicular to it and exactly opposite one eye (the other being closed). The centre of the stick was then held so as to appear directly over the centre of the Moon's disc, and the distance in inches read off, to any star or planet which appeared close to the Sun during the total phase of the eclipse. Mr. KELLOGG observed a bright star one inch from the center of the Moon and a little below a horizontal line drawn from the centre of the Moon to the left.*

This observation was made with the naked eye.

LINCOLN HUTCHINSON.

*Mercury.

Details of Exposures and Developments of Plates.

Number of Plate	Time of Exposure.	Second of Beginning Exposure* (Estimated.)	Second of Ending Exposure (Estimated).	Development. † Passavant's Pyro Developer. Solution No. 1. Distilled Water, 8 oz. Sulphite soda, 2 oz. Citric acid, 60 grs. Pyrogallic acid, 1 oz.	Solution No. 2. Carbonate potash, 8 oz. Sulphite soda, 2 oz. Distilled water, 16 oz.	Water.	Time of Development.	Remarks.
1.	Quickest possible hand exposure.	4th second.	$4\frac{1}{2}$.	1 drachm.	$\frac{1}{3}$ drachm. $\frac{1}{3}$ drachm after 5 min. $\frac{1}{3}$ drachm after 10 min.	5 oz.	Image appeared in 3 min. In solution 20 min.	Camera shook slightly.
2.	2 sec.	13th.	15th.	$\frac{1}{2}$ drachm. $\frac{1}{4}$ drachm after 6 min.	$\frac{1}{3}$ drachm. $\frac{1}{3}$ drachm after 10 min. $\frac{1}{3}$ drachm after 20 min.	5 oz.	Image appeared in $2\frac{1}{4}$ min. In solution 22 min.	
5.	6 sec.	27th.	33d.	$\frac{1}{3}$ drachm. $\frac{1}{3}$ drachm after 8 min.	$\frac{1}{3}$ drachm. $\frac{1}{6}$ drachm after 10 min.	5 oz.	Image appeared in 1 min. In solution 23 min.	
6.	12 sec.	42d.	54th.	$\frac{1}{3}$ drachm. $\frac{1}{3}$ drachm after 5 min.	$\frac{1}{3}$ drachm. $\frac{1}{6}$ drachm after 7 min. $\frac{1}{6}$ drachm after 17 min.	5 oz.	Image appeared in 1 min. In solution 23 min.	
7.	20 sec.	65th.	85th.	$\frac{1}{3}$ drachm. $\frac{1}{3}$ drachm after 13 min. Fresh Developer after 35 min. $\frac{1}{3}$ drachm.	$\frac{1}{2}$ drachm. $\frac{1}{4}$ drachm after 1 min. $\frac{1}{4}$ drachm after 6 min. $\frac{1}{2}$ drachm. $\frac{1}{3}$ drachm after 3 min.	5 oz. 5 oz. $\frac{1}{2}$ oz. after 3 min.	Image appeared in $\frac{1}{2}$ min. In solution 45 min.	

8.	4 sec.	95th.	99th.	$\frac{1}{3}$ drachm.	$\frac{1}{3}$ drachm. $\frac{1}{6}$ drachm after 15 min. $\frac{1}{6}$ drachm after 29 min. $\frac{1}{6}$ drachm after 35 min. $\frac{1}{6}$ drachm after 45 min.	6 oz. 1 oz. after $2\frac{1}{2}$ min.	Image appeared in $1\frac{1}{2}$ min. In solution 72 min.	One end broken several days after development.
				Fresh Developer after 55 min.				
				$\frac{1}{3}$ drachm. $\frac{1}{3}$ drachm after 69 min.	$\frac{1}{2}$ drachm. $\frac{1}{4}$ drachm after 64 min.	5 oz.		

* Totality lasted about 102 seconds.
† Passavant's Normal Developer—1 drachm, No. 1; 1 drachm, No. 2; 5 oz. water.

Notes on Mr. Hutchinson's Negatives.

The image of the Moon on these negatives is nearly 0.3 inches in diameter, and although the definition is not perfectly sharp, owing to the nature of the lens employed, they would have shown a large amount of detail if the camera had been provided with an equatorial mounting. As it is, the detail in the long exposures, especially near the poles, is obliterated by the motion of the image. Plate No. 1 appears to have been jarred in exposing, as the image is double. *Mercury* appears on all the plates except No. 1, and makes a strong trail on No. 7, as do also the prominences. On No. 7 the greatest extension of the outer Corona is 60′ from the Moon's centre. The polar rays are best shown on No. 5, with six seconds exposure, but even in this the motion of the image has blurred the outlines.

Report of Mr. J. S. Hutchinson.

Station—A hill about two miles southwest of town of Cloverdale; 1,000 feet elevation above the Sonoma Valley.

Provided with a good marine glass and piece of smoked glass, I stood intently watching the advance of the Moon across the Sun's disc. When only a hair line of light was visible, could see nothing but the dark face of the Moon until the instant of totality, when, like a flash, a gorgeous halo appeared, I judged one eighth of the diameter of the Moon. The smoked glass was discarded and the magnificent sight viewed with the naked eye. The color next the Moon was silvery white, then a bright pink shading off into yellow at the outer rim. A second or two later, streamers of yellow light appeared to shoot out right and left, extending from the outer rim of the halo a distance equal to one and a half times the Moon's diameter at the upper and lower edges of this band of light, while the middle portion was much shorter. Two stars were visible to the eye. At no time was darkness so great that I could not read the time by my watch, and see the configuration of the landscape; it appeared as if seen through a glass densely smoked. I failed to catch sight of the sweep of the black shadow across the country, although our location was selected expressly with a view to watching for this. A few minutes preceding totality, and just after, rainbow hues appeared to the right and below the Sun at some distance.

J. S. Hutchinson,
Cloverdale, Cal.

January 1, 1889.

Report of Mr. E. C. Hutchinson.

Enclosed are reports of barometer, thermometer, and stop-watch readings, taken on "Bald Mountain," a few miles south of Cloverdale, California.

Instruments used:

Barometer—London standard compensated pocket aneroid. This was regulated on Monday, the 31st of December, by THOMAS TENNENT.

Thermometer—A self-registering thermometer.

Stop-watch—Large faced watch, made in Locle, Switzerland; the second-hand being full diameter of face.

My barometer was divided into tenths, so that I could not get the exact reading, which was just a trifle short of 29-inch mark. I noted it some time prior to totality, and also after totality, and could not detect any change at all in the needle from readings given on card.

The thermometer remained unmolested for 15 or 20 minutes after totality, and thus registered the lowest point. It was hung on the branch of a tree, and was in the shade. When taken down the mercury had commenced to rise.

As totality approached, I held my watch up in front of me against the smoked glass, and was thus able to keep both the Sun and it in view at the same time. I checked time with Mr. R. R. DEMPSTER, exactly, and started my watch. As the end of total obscurity drew near, I again held my watch up in front of me, and again checked "time," but failed to stop the watch until four (4) seconds after. The face was in plain sight, and the second-hand being the full diameter of the face, I had no difficulty in counting the seconds between "time," and when the watch was stopped.

I feel confident that the time of totality was 1 min. 41¼ sec., provided "time" was called correctly, and we were very careful in this, but of course had no experience of this kind before.

Just prior to totality the light clouds in the vicinity of the Sun (the sky all around the Sun was filled with very light clouds, but there seemed to be none directly between us and the Sun) to the southwest, or in the path over which the Moon had just passed, were colored with all the colors of the rainbow. This coloring seemed to be taken on suddenly, and I do not think changed or increased any.

No wind was blowing, the atmosphere being exceedingly quiet. I did not notice any deposit of dew.

The Moon near its centre seemed to be of sea-green color, the edges appearing very black. This was noted and spoken of by several of the party.

The inner Corona appeared very suddenly, and completely encircled the Moon's disc. It was much brighter than the outer. It extended out about one sixth of the diameter of the Moon, and was equally bright throughout the whole circle.

The outer Corona extended out on two sides of the Sun in the path the Moon was traveling; that to the southwest appearing considerably the longer, the longer streamer extending out about one and a third times the diameter of the Moon. The outside edges of the streamers seemed the brightest.

According to instructions given in the Naval Observatory Report for the Eclipse of 1878, I prepared several papers for drawings and gave to those of the party who expressed a desire to attempt a drawing of the Corona. They were instructed to give special attention to the direction and extent of the outer Corona.

The ink lines on the drawings were extended beyond the circumference of the black center $1\frac{1}{4}''$, corresponding with its diameter.

The lines are at an angle of 30 degrees. The results are poor.

Yours very respectfully,

E. C. HUTCHINSON.

Care Giant Powder Co., No. 30 California Street, San Francisco, California.

Stop Watch.	*Thermometer.*	*Barometer.*
1st stop, 1 hr., 0 min., 0 sec.	1 hr., 29 min. ...51° Fahr.	1 hr., 20 min.........29 in.
2d stop, 1 hr., 1 min., $45\frac{1}{4}$ sec.	1 hr., 35 min. ...50° Fahr.	1 hr., 36 min.........29 in.
(4 seconds too long).	1 hr., 53 min. ...48° Fahr.	1 hr., 42 min..29 in., slack.
	Self-registering.	1 hr., 44 min..29 in., slack.
		1 hr., 48 min.. 29 in., slack.
		1 hr., 51 min..29 in., slack.

Report of Mr. M. R. Dempster.

36 GLEN PARK AVENUE,
SAN FRANCISCO, January 16, 1889.

I accompanied a party of amateur observers, which went to Cloverdale from this city on January first last, to observe the Total Eclipse of the Sun which occurred on that day. The list of the members of our party, a description of the instruments used, and a description of our point of observation, having been written by Mr. LINCOLN HUTCHINSON, I will confine my account to the part of the work I performed and to the occurrences I witnessed.

I had volunteered to take and record the time of second and third contacts, the instants of their occurrence being given by my brother, Roy R. Dempster, who observed them with a telescope. The watch used was one made by Jules Jürgensen, of Copenhagen. I was provided with a small sheet of paper, mounted upon cardboard and having marked upon it the hour, and spaces for minutes and seconds for each contact.

When the time for totality had nearly arrived, I took my position near my brother's telescope, lying flat upon the ground, and holding the watch before me, directly in the light of a dark lantern, which was under my face. My brother notified me about thirty seconds before the Sun's disappearance, and I began counting the seconds aloud, and continued counting until he called "time." I noted the exact second, and then looked up at the eclipse. Immediately after, one of the party asked me what the time was; I told him "23 seconds," and at once wrote the figures in the proper place, and then examined the watch face to ascertain the minute, which I thought to be 47 minutes past one, and wrote that on the paper also. I then spent a few seconds observing the eclipse, and when my brother notified me that totality was nearly over, I again began counting seconds. Upon his calling "time," I noted the exact second, and wrote it down at once, and then ascertained the number of minutes past one, and wrote that figure in its proper place. The memorandum reads as follows:

Contacts: Total, $1^h\ 47^m\ 23^s$.
End, 1 48 5.

It is evident that I made a mistake of one full minute in the time of totality. On my original memorandum, sent herewith, you will observe that I have made a correction, but I now doubt if the correction is in the proper place. Inside of fifteen minutes after totality, I performed a subtraction to ascertain the length of the total eclipse, when I discovered that I had made a mistake of one minute in writing the figures. I concluded the mistake was made in the time of third contact, and made a note to that effect on my memorandum; but since returning home my friends have learned that if the mistake is in the time of second contact instead of the third, the time at which the eclipse occurred will be very near the time it was predicted for at our point of observation.

The watch used was a few seconds slow by the Lick Observatory time. We are not sure of the exact number of seconds of

its error, by reason of the unsatisfactory telephone service between this city and the Observatory.

Probably the only value of my work will be for ascertaining the duration of the eclipse. I think it is accurate in regard to the seconds. I paid particular attention to getting them correctly and thought but little of the minutes, and in my hurry to get a few moments for personal observation I probably made the error in the time of first contact of totality.

Shortly before totality I saw, with others of the party, rainbow colors in a thin cloud very near the Sun.

While counting the seconds, before second contact, the darkness increased so much that I could not discern the fine marks on the watch face by sunlight, and had to trust entirely to the lantern for a few beats; but apparently the light increased immediately so that I could dispense entirely with the lantern. I counted the seconds for third contact entirely by natural light. Probably there was no increase of light immediately after totality began, and it may be I was led to think there was an increase because my eyes had become accustomed to the darkness.

During totality I saw two stars, undoubtedly *Venus* and *Mars;* and some seconds after totality I noticed diffraction bands passing over the ground from southwest to northeast.

Yours very respectfully,

M. R. Dempster.

Mr. Lincoln Hutchinson.

Report of Mr. Roy R. Dempster.

I observed the eclipse through a spyglass, object glass $1\frac{1}{2}$ inches in diameter, focal length about 1 foot 1 inch. Just before totality I observed that the Sun's crescent was broken into small parts. I then removed the smoked glass which I had held in my hand between my eye and the eyepiece, and called "time" just as the glare disappeared, I think exactly on the second. Several red prominences projected beyond the Moon. I had no difficulty in telling the time of ending. Before the total phase I saw prismatic colors in a cloud a few degrees from the Sun. I could see no well defined shadow, but a few seconds after calling "time" at third contact saw the diffraction shadows crossing the ground. The above notes were written immediately after totality.

Roy R. Dempster.

Mr. Lincoln Hutchinson.

Meteorological Observations by Roy R. Dempster.

Time.	Dry Bulb.	Wet Bulb.
1h 25m	10½° C.	7° C.
1 35	10	6
1 42½	9½	6
1 44	9½	6
1 48	9	5¾
1 51	9¼	6
1 53 (?)	9	6

Cloverdale, California.

C. Mason Kinne, Observer.

A naked eye drawing of the Corona was made, showing slightly divergent equatorial streamers of the fish-tail shape, extending nearly two diameters from the limb of the Moon. The polar rays are also shown. The color of the sky is described as a "steely blue." See also report of A. J. Treat, p. 153.

Cloverdale, California.

Lawrence H. Pierson, Observer.

The Corona was observed with a powerful marine glass and a drawing made after totality. It shows the fish-tail streamers extending about 1½ diameters from the Moon, and the polar rays.

Cloverdale, California.

Miss Sylvia Rey, Observer.

A naked-eye sketch of the Corona was made during totality, showing the fish-tail streamers slightly divergent on the west side, and slightly convergent on the east side of the Moon. Polar rays faintly indicated. See also the report of A. J. Treat, p. 153.

Cloverdale, California.

Emmet Rixford, Observer.

Six negatives were secured during totality, with a lens taken from a terrestrial telescope, having an aperture of 2 inches and a focal length of about 25 inches.

No. 3. Exposure 1^s Cramer lightning plate, sensitometer, 40.
No. 4. Exposure 2^s Cramer lightning plate, sensitometer, 40.
No. 5. Exposure 10^s Kingston special, a slow plate.
No. 6. Exposure 12^s Kingston special, a slow plate.

Normal oxalate and iron (1 to 6) developer; and development continued to from 10 to 15 minutes.

The images of the Moon, about 0.2 in. in diameter, are not perfectly sharp, owing probably to the nature of the lens employed. The exposures are well chosen to bring out the details of the inner and outer Corona, but much was lost by the motion of the image. *Mercury* is indistinctly shown in the first two negatives.

CLOVERDALE, CALIFORNIA.

MISS M. C. ROBERTSON, Observer.

A naked eye drawing of the Corona was made, showing a general equatorial extension.

CLOVERDALE, CALIFORNIA.

MRS. LAURA B. ROE, Observer.

Two colored sketches were made, representing very satisfactorily the appearance of the Corona to the naked eye. The fish-tail streamers are yellowish in tint; the sky is bluish green. The polar rays are not separately shown. See also the report of A. J. TREAT, p. 153.

CLOVERDALE, CALIFORNIA.

LEWIS TASHEIRA, Observer.

A naked-eye drawing of the Corona was made, showing convergent fish-tail streamers on the east and west of the Sun, and two prominences. Extent of the streamers, one diameter from the Moon's limb. The polar rays are not separately shown.

CLOVERDALE, CALIFORNIA.

MISS NELLIE L. TREAT, Observer.

A naked-eye sketch of the Corona was made during totality, and an oil sketch afterwards. The color of the inner Corona is "an intense, luminous pale blue," and the coronal streamers are

slightly tinged with yellow.* On the west the equatorial streamers extend about 1½ diameters from the limb of the Moon; on the east, less than one diameter. The northeast streamer is short. The color of the Moon is deep purple. No polar rays are shown. The pencil sketch shows the southwest edge of the outer coronal streamer as far as 89′ from the Moon's centre.

Cloverdale, California.

Mrs. A. W. Truesdell, Observer.

A naked-eye sketch of the Corona was made during totality, showing fish-tail streamers extending east and west of the Moon, those on the west to a distance of 1¾ diameters. The eastern streamers are shorter. The polar rays are indicated.

Cloverdale, California.

Dr. J. H. Wythe, Observer.

The Corona was observed with a 2½-inch telescope, having a power of 50 diameters. A pencil sketch was made during totality, and a water color sketch afterward. They show a general equatorial extension of the Corona, and radial polar rays on the northern limb of the Moon. On the southern limb they are merely indicated. Two prominences are shown.

The cusps of the Sun, just before totality, were blunted. This was also seen by other observers.

Contacts were observed as follows:

First contact	$0^h\ 22^m\ 30^s$.
Second contact	1 40 45.

Watch correction not given.

Covelo, Mendocino County, California.

E. B. Bateman, M.D., and Hermann Puck, Observers.

Beginning of eclipse	0^h	19^m	45^s	[No watch correction given by the observer.]
Beginning of totality	1	35	3	
Duration of totality	0	1	17	
Duration of eclipse	1	47	29	

Clouds prevented any observation of the diffraction bands. Two drawings of the Corona were made.

*See however the report of A. J. Treat, p. 153.

Emigrant Gap, Placer County, California.

F. W. Leach and J. H. Garby, Observers.

The following record was made of the times of contacts:

First contact	$12^h\ 27^m$
Second contact	1 52
Third contact	1 53
Fourth contact	3 07

No description of methods is given.

Grass Valley, Nevada County, California.

W. W. Deamer, Observer.

The duration of totality was observed by means of a piece of smoked glass and an ordinary watch, and found to be $1^m\ 11^s$.

Healdsburg, Sonoma County, California.

Geo. Edward Hall, Observer.

A number of prints from negatives and photographs of drawings were sent to the Lick Observatory. The photographs of the Corona were taken with apparatus not described, but the lens must have had a focal length of about 30 inches. A general equatorial extension of the Corona is shown.

Hopland, Mendocino County, California.

. B. Rodolph and C. D. Perrine, Observers.

Contacts were observed, photographs taken, and general phenomena of the eclipse noted. The station was 4 miles N. 46° E. from Sanel Mountain, near Hopland.

Contact Observations.—The first and fourth contacts were observed with a spyglass magnifying 16 diameters; the second and third were observed with the naked eye. The watch which was used was compared with the Merchants Exchange clock in San Francisco, on December 31, 1888, and again on January 2, 1889. In this interval it had gained 30 seconds, and the watch corrections at the time of the eclipse were obtained by interpolation to the nearest second.

Contact.	Observed Time.	Watch Correction.	Pacific Time.
1	12h 22m 28s	—10s	12h 22m 18s
2	1 46 28	—11	1 46 17
3	1 48 28	—11	1 48 17
4	3 6 54	—11	3 6 43

General Observations.—The sky was entirely cloudy at 11 A. M., but clear at time of first contact. It was clear during totality and at the fourth contact, and occasionally obscured between these times.

As totality approached, the light became first yellow in tinge, then a deep orange, and finally a livid light preceded the second contact. A reddish flash was noticed just as the last ray of sunlight disappeared. The Corona shone with a soft, silvery light, slightly tinged with blue, especially in the outer streamers. It appeared to be suspended in space, and much closer to the Earth than the Moon. Surrounding objects were plainly visible during totality. The temperature was lower and a decided chill was felt. The height of the station above sea level was 677 feet.

Photographs.—Eight negatives were obtained with the back combination of a SUTTER lens, No. 3, having a focus of 16 inches. The image of the Moon on the negatives is abont 0.15 inches in diameter.

Number of Negative.	Stop Used.	Lens.	Exposure.	Developer.
2	No. 2	Sutter No. 3	2s	Hydroquinone.
4	No. 2	Sutter No. 3	6	Hydroquinone.
5	No. 2	Sutter No. 3	10	Hydroquinone.
6	F/32	Sutter No. 4	12	Pyro-potash.
7	No. 2	Sutter No. 4	6	Hydroquinone.
8	No. 2	Sutter No. 4	2	Hydroquinone.

The plates used were SEED No. 26.

No. 2 shows the inner Corona to about curve *a* of figure 1, Plate III. No. 4, with 6 seconds exposure, is about the same as No. 2, perhaps on account of shorter development. No. 5 with 10 seconds, and No. 6 with 12 seconds exposure are alike except in size, No. 6 being much smaller. Both show the planet *Mercury* indistinctly. No. 8 shows only the brightest part of the inner Corona, as far as curve *k* of the photometric diagram, figure 1, Plate III.

KIBESILLAH, MENDOCINO COUNTY, CALIFORNIA.

H. E. WHIPPLE, Observer.

The eclipse began at	0^h	25^m	52^s
Totality began	1	49	25
Totality ended	1	50	0
Duration of totality		0	35

Correction to watch not given. Clouds prevented observation of the fourth contact.

The Corona appeared to be brightest above the Moon.

LIEGAN, CALIFORNIA.

Report of C. W. IRISH, U. S. Surveyor-General of Nevada.

U. S. SURVEYOR-GENERAL'S OFFICE,
RENO, NEVADA, March 16, 1889.

Professor EDWARD S. HOLDEN, *Director Lick Observatory, Mt. Hamilton, California:*

MY DEAR SIR: With this I am pleased to enclose my written description of my observations of the Total Solar Eclipse, made at Liegan, California. I shall in a day or two make a few more positives and send you.

Very truly yours,

CHARLES W. IRISH.

Total Eclipse of the Sun, January 1, 1889, as observed by the Nevada State Observation Party.

Liegan, California, at the present terminus of the California and Oregon Railway, was our station. It is a new town situated on Section 13, in Township 27 N., R. 16 E., Mt. Diablo meridian, and is six and one half miles west from the 120th meridian. The longitude in time is approximately $8^h\ 0^m\ 29\frac{4}{10}^s$ W.; latitude, approximately, 40° $9\frac{3}{4}'$ N.; altitude, 4,050 above the sea. The altitude was given me by L. F. WARNER, Esq., Chief Engineer of the Northern California and Oregon Railway, and is determined with accuracy by engineers' levels.

The weather for several days before the 1st was very cloudy, so much so that only an approximate meridian could be obtained, and no observations of precision could be made for obtaining local time until noon of the 1st; clouds attended us then and

until time of 1st contact, but did not materially interfere with us after that.

The upper regions of the atmosphere were much disturbed by a warm southeast current coming in contact with a cold one from the west. This gave the air in the vicinity of the eclipse much tremulous motion at about the time of 1st contact, but during totality and on to the end of the eclipse it was hardly noticed. After 4th contact clouds again gathered, and at sundown shut the sky entirely from view.

I was assisted by Professor C. W. Friend, of Carson, Nevada, who took the contacts, assisted by Hon. Tremnor Coffin. I myself took the contacts, assisted by Mrs. C. W. Irish.

I put the photographic work into the hands of Professor L. P. Butler, of Reno, Nevada, and Mr. James W. Moffat, Civil Engineer, of Silver Peak, Nevada.

Professor Butler was assisted by Mr. Sidney Pinniger, who changed the plate-holders for him, and Mr. Moffat by Professor W. McN. Miller, of the Nevada State University, who performed the same service for Mr. Moffat.

Professor Miller joined the party for the purpose of making meteorological observations of his own, and as I was short a man for the photographic work, he kindly volunteered for the purpose.

Mr. J. S. Hawkins, of Carson, Nevada, by means of a sighting tube and tangent screw attached to the platform upon which the photographic cameras were fixed, kept these instruments pointed upon the Sun, and Mr. L. F. Warner called the times the exposures began from the face of the chronometer and recorded them.

As I was watching for 1st contact, I had the good fortune to catch a view of the Moon as it closely approached the Sun. I could not see the entire body of the Moon, but only a crescent formed part of it. An arc of about 45° in extent was plainly seen; it was of a silvery gray tint, very sharp and well defined on edge next to the Sun and fading away to invisibility, and was lost at about 20° each way from the point nearest to the Sun. It was in breadth one third the diameter towards the center of the Moon from the advancing edge. Thus I was able to call time of exact 1st contact, and half a second later saw the black edge of the Moon's disc overlap the brilliant limb of the Sun.*

*I have asked General Irish for drawings of this appearance, but he has not yet forwarded them.—E. S. H.

The photographic party now began their work, taking several drop shutter views of the partial phases.

As the total phases approached closely, I could plainly perceive that yellow rays predominated in the waning sunlight, and things illuminated by it wore the ghastly livid look, as if illuminated by a salted flame. The landscape partook of this deathly pallor. A few seconds before 2d contact, diffraction bands began to appear, their lengths disposed north and south, and their motion towards the east. I saw them at first faintly depicted upon the canvas of my tent, and as they brightened they were seen creeping along the ground surface; their motion, I judged, was about from six to ten feet per second eastward.

When the instant of 2d contact came, the Sun's chromosphere seemed to leap out of that point of the Moon's limb where contact took place, and springing around the circle of the Moon in opposite directions, clasped it as if in a loving pair of arms. At the same time the Corona, which before was faintly seen, flashed out upon the ashy purple sky. At the end of the article I give four sketches* of it, made by members of the party, 2d and 3d are duplicates.

The Corona had two double pointed rays, one of them about tangent to the Sun's upper limb, the other tangent to the lower limb. The outer edges of these were straight lines or nearly so; they appeared to me to be exactly parallel, and if they deviated in their lengths from a straight line, it was where they came in contact with the Sun's limb, where they seemed to curve outward around it. The rays had a direction in space, upward from a line through the Sun's centre parallel with the horizon, of about 27°, rising towards the east. The westward point of the upper ray reached out towards the west about 1½ diameters of the Sun from its centre, and the eastward point towards east 1¼, the westward point of the lower ray 2, and its eastward point 1½ such diameters.

The inner edges of these rays curved inward toward each other, and meeting, formed a fringe of pure white light to the Sun's limb, about one half diameter broad. The two western rays, together with the included fringe, were by far the brightest part of the Corona, while the two eastern were, with their included fringe, the faintest.

*Omitted. These sketches are reproduced in the *Sidereal Messenger* for April, 1889.

The upper eastern ray was much the weakest of all. The Corona in density, brightness, and species of its light, reminded me strongly of the great nebula of Orion, when I view the latter with my 4-inch telescope, with a power of 20 times. I saw several stars in vicinity of the eclipse, twinkling brightly, and on looking overhead, eastward and northward, saw many more, but I was too much occupied in sketching the Corona to take any note of them. The Sun's polar rays flashed out in a broad light fan from both poles, extending, as I judged, three fourths of a diameter; they blended with the Corona's light, and gave to that its outward, curved appearance. I paid but little attention to the Sun's chromosphere, as I had not the time to do so. The red prominences were quite evident to the unaided eye, principally on the western limb of the Moon.

A short view of them with my telescope showed the two, which were noted by the observers by naked eye observation, to be enormous in proportions; the one in the axis of the upper western ray, was sharply spear-shaped, and of quite recent formation. Its shape and appearance reminded me strongly of a view I had some years since of the formation of just such a figure on the Sun's surface in pure white. The other prominence appeared in the axis of the lower western ray, was cone-shaped, the apex bent upward somewhat, and from it there floated off three beautiful roseate clouds, in the direction to which the bended apex pointed; these clouds were cumulus in form.

A number of small and very red prominences appeared in the axis of the lower eastward coronal ray; they seemed to be just forming. In base of the upper ray, near to its edge, appeared a cone-shaped prominence, having a hue of ashes of roses; it was evidently dying away, for it seemed to be settling down to the surface of the sun.

The red points of other prominences could be seen peeping up from behind the black limb of the Moon, but I took no further note of them. The chromosphere to my eye had the appearance of a rose-colored spherical shell enclosing the sun at a distance of one twentieth of his diameter, from him, lighted up by roseate fires, which were hidden from my view by the dark body of the Moon. After third contact, I watched the parts of the beautiful scene as they one by one faded from my view.

The chromosphere parted at the point of third contact and withdrew each way from it to disappear at the opposite side of the Moon.

It disappeared altogether in about 3 seconds. But the beautiful Corona lingered, its eastern rays dissolving in about 15 to 18 seconds, and its brighter western rays in about 20 seconds after third contact.

The diffraction bands and the retreating shadow now claimed my attention. The bands seemed brighter than before totality, and danced along like reflected sunlight from faint ripples of a broad water surface. Their peculiar motion caused me to remark that their origin might be discovered in the wave-like tremulous motion of the air, described at the beginning of the eclipse. The shadow was seen creeping away eastward over the plain and along the mountain side, its motion not as swift as I expected it to appear. I had no trouble in following the limb of the Moon to exact fourth contact, and continued to see the slaty gray crescent for about three seconds after that.

Again the photographic party took photographs, at convenient intervals of time, of the now declining eclipse, and observers completed their sketches before the figures faded from memory; this was religiously done; no comment or communication with each other until it was done. At noon of the 2d, we secured two reliable observations for time over our approximate meridian, and having in the forenoon pulled down our camp and packed our instruments, we left on the N. C. and O. train for Reno.

My observed times of the four contacts, referred to the chronometer and corrected for its rate, and differences between noon of the 1st and 2d, by our approximate meridian, were as follows:

1st,	0^h	29^m	$04^s.6$	P. M. January 1, 1889.
2d,	1	51	15.0	P. M. January 1, 1889.
3d,	1	53	00.6	P. M. January 1, 1889.
4th,	3	09	55.5	P. M. January 1, 1889.

Professor Friend and Hon. Tremnor Coffin jointly report as follows: "Diffraction bands were not noticed at the beginning of totality; the Corona on each side of the Sun somewhat resembled an enlongated tail fin of a fish, with the outer edge fairly well defined, and with the inner edge shadowing off into invisibility. The four points seemed to extend out into long, single hair-like rays of indefinite length, losing themselves in the brighter outer sky. Point *d* (figure 2) was discernable for at least two diameters of the Sun. The relative lengths of the four points were in the order, *d*, *b*, *c*, *a*. The rifts in the points *a–c* and *b–d* were deeper, or extended nearer to the Sun's limb, towards the line

a–b, than on the side of the line *c–d*. I made no attempt to observe anything except the form and appearance of the Corona, and to look for the diffraction bands before and after totality. The sketch (No. 3) was made in camp at Liegan, on the morning of January 2; it would be difficult, if not impossible, to represent the Corona as it really appeared. In color, it was a very light, soft yellow, with a greenish tint. The points of the Corona, especially the lower right-hand point, seemed to extend out into long luminous hairs, which appeared to float in space. There was a gradual decrease of light from the limb of the Sun to outer limits of the Corona. Referring to sketch (No. 2) there was no sharply defined outline, except a part of line *a–b*; lines *a–b* and *c–d* should be a little nearer or quite parallel, by widening the space between *a* and *c*, and narrowing the space between *b d*. The lines across diagram and about the eclipse are intended to represent very light cirro-stratus clouds, nearly all other parts of the sky clear. The approach and recession of shadow not clear cut nor well defined. The light faded gradually into dull twilight, and vice versa; diffraction bands not noticed before totality, but sharply defined for four or five seconds after third contact; they were without perceptible onward motion. They appeared like the quivering light cast upon a wall by innumerable wavelets upon nearly still water in sunlight.

No candle was necessary for the reading of my watch, or to make the drawing during totality. Two small red prominences were seen by the unaided eye. The Corona was not visible before second, nor after third contact. Times of observation by Professor FRIEND:

1st,	0^h	29^m	03^s	.4,	January 1, 1889.
2d,	1	51	16	.3,	January 1, 1889.
3d,	1	53	00	.3,	January 1, 1889.
4th,	3	09	38	.4,	January 1, 1889.

Professor FRIEND concurs in the foregoing which I have written."

Very respectfully,

TREMNOR COFFIN.

RENO, NEVADA, January 25, 1889.

Gen. C. W. IRISH, *Director of Eclipse Observation Party:*

SIR: I have the honor to report to you the result of my part in the observation of the Total Eclipse of the Sun on the 1st instant, at Liegan, California. I, by your direction, took charge of the

DARLOT single view lens and camera. The glass was 18 inches back focus, and was about 3 inches in diameter, with a maximum stop opening 1 inch in diameter. It was provided with two stops of smaller diameters, but all the work upon the total phase was done with the full opening of one inch. I was assisted in the work at the camera by Prof. W. McN. MILLER, who changed plates for me and managed that part of the work, while I made the exposures and counted the times of the same by the second hand of my watch. Attached is a tabular statement, giving the history of each plate. It is as follows:

Photographic plates exposed by J. W. Moffat, C.E., and Prof. W. McN. Miller, with the Darlot lens.

PLATE No.	Chron. Time the Exposures Began	Time Exposed.	Remarks.
7	1h 12m 01s	Inst.	View of observation of grounds.
8	1 16 46	Inst.	Partial phase covered by clouds.
9	1 21 02	Inst.	Partial phase, good definition.
10	1 47 46	Inst.	Shows fan-shaped light.
11	1 51 15	4 secs.	Totality.
12	1 51 28	5 secs.	Totality.
13	1 52 02	7 secs.	Totality.
14	1 53 58	5 secs.	Not exposed.
15			
16	1 53 01	5 secs.	Caught by Sun at end of totality and jarred.
19	1 58 01	Inst.	Same as No. 10.
20	2 22 47	Inst.	Sun covered by thin clouds.
21	2 50 48	Inst.	

All the plates used during the observation of the eclipse were SEEDS, sensitometer No. 26, and were developed by myself and Prof. BUTLER, who will give description of the developer used; it is a weaker one than is usually used upon these plates.

I would call your attention to the peculiar fan-shaped light shown by Nos. 10 and 19, which were exposed within 4 and 5 minutes of totality; No. 10 before and No. 19 after that event.

Respectfully yours,

JAS. W. MOFFAT, C.E.

Gen. C. W. IRISH, *Director of the Nevada Eclipse Observation Party:*

SIR: I take much pleasure in reporting to you in conjunction with Mr. MOFFAT the results of our photographic work on the recent eclipse, January 1, 1889.

The following table shows a history of the plates which I exposed at the time of total observation, using a SUTER lens, Swiss make, No. 3, of the doublet form, 3-inch full opening of the front

combination, and 16 inches back focus. I was provided with three stops, but I used the full opening of 3 inches during the work upon totality. I made the exposures and timed them by counting (mentally) the seconds. It was a happy conception of yours to experiment with the cameras and lenses, by making exposures of some plates sighted upon Mt. Rose, fifteen miles away, after sunset, and the stars had shown themselves in the evening twilight. Upon development of these trial plates, the mountain ridges and slopes, together with the figures of the pine trees, came out clear cut, and with an exposure of only five seconds with full aperture of the lenses. The developer used upon the trial and eclipse plates, was that of Prof. NETWON, "standard dry pyro" as follows: One oz. carbonate soda dry, one oz. carbonate potash dry, one oz. sulphite soda dry, ten oz. of water, six grains of pyro dry; put into four ounces of water and dissolved, to which add two drams of the alkali solution; the mixture makes sufficient developer for a 5x3 plate.

I think, General, that we may congratulate ourselves upon having attained such perfect results, photographically, of all the phases of the eclipse, while using the rude and hastily improvised stand and appliances, fashioned from materials found upon a desert waste.

In conclusion, I have to say, that all the plates, whether shutter or cap exposures, show images which came out quite vigorously during development. The cap exposures made during totality with open lenses though so variously timed, obeyed the requirements of development easily and without any forcing or prolongation of time or patience.

The axis of the platform on which was fastened the cameras in use, was so arranged that the DARLOT lens, being placed over the pivot about which the whole apparatus revolved, showed less movement and disturbance from the jarring incident to removing and replacing the plate-holders in the camera, than did the SUTER lens, which was further away from said pivot. I would infer from this, that every camera in such use should have its own separate support.

The following is a tabulated statement of the plates exposed by me. I took no photographs of partial phases, having no drop shutter to my lens:

Plate No.	Chron. Time.	Time Exposed	Remarks.
33	1h 51m 15s	3s	Excellent, good definition.
34	1 51 41	4	Shows signs of jar during exposure.
35	1 52 08	1	Badly jarred.
36	1 52 22	5	
37	1 52 44	3	
38	1 53 01	2	Caught by end of totality, excellent definit'n.

Sincerely yours,

Prof. E. P. Butler.

In preparing for photographic work upon the eclipse, I was ably seconded by Prof. Butler, whose long experience in the lights and shadows of the mountains of California and Nevada was a training much needed for such work. He cheerfully consented to assist, and together we made experiments with the two lenses selected for our work, by exposure with "Seed plates" after sunset at times selected by myself, at which the darkness of receding twilight was first a little brighter than I had in former experience with total eclipses observed the light on such occasions to be; and second when the still fading twilight was surely a shade or two darker. To this end I selected the pine covered slopes of the Sierra Nevadas, distant about fifteen miles. The newly fallen snow caused the black pine trees to stand out boldly in relief on the sides of the mountain known as Rose Peak. We focused the cameras carefully upon clouds, which hovered over the mountains in bright sunlight, and marked the position of the plate carriers, and then on the evenings of December 27th and 28th, preceding the eclipse, we pointed the cameras upon the mountain selected, and at 25 minutes after sundown, at a time when the unaided eye could clearly make out the pine trees on the mountain sides, made exposures with the medium stops of five seconds; at thirty minutes after sunset, exposures of ten seconds, at a time when I judged by the eye that the darkness was about as we might expect it during the eclipse; and again at forty minutes, when the pine trees had lost their forms to the eye, and only the bulk of the mountain could be outlined upon the sky and clouds as a background. At this time we made exposures of from 5 to 10 seconds, with full opening of lenses, getting negatives which not only gave an outline of the clouds and mountains, but also of the pine trees on the darkly shadowed slopes. The figures of the pines are clear cut, showing that our cameras

could catch forms in a light so weak that the eye altogether failed in the attempt to make them out. I found by comparison on the day of the eclipse that the darkness was just about equivalent to the forty minutes after sundown experiment.

I here give the four field sketches made at the time of the eclipse, and a photograph from negatives made by each of the lenses used. A by the DARLOT and B by the SUTER. The figure of the Moon in photograph A shows the same crescentic reflection as I saw it in the telescope to have, which enabled me to see the Moon before second contact, and after third.

Not one of the negatives by this lens shows more than a suspicion of the presence of the red prominences, while in every one by the SUTER they strongly appear.

We were very kindly treated by the people of Liegan, and owe a debt of gratitude to E. GEST, Esq., Manager, and Mr. J. M. FULTON, Superintendent, and to L. F. WARNER, C.E., of N. C. and O. Ry. Co., and Mr. ROBERT L. FULTON, for transportation and other help furnished the expedition, without which we could not have succeeded.

CHAS. W. IRISH,
U. S. Surveyor-General of Nevada, Director of the Party.

LOWER LAKE, LAKE COUNTY, CALIFORNIA.

MESSRS. BEAKBANE AND HERTSLET, Observers.

Two negatives of totality were obtained and prints from them furnished to the Lick Observatory.

TOWNSHIP 11 N.; RANGE 7 W.; LAKE COUNTY, CALIFORNIA.

WRIGHT MATHEWS, Lower Lake, Obse ver.

	h	m	s	
First contact	0	23	59	[No watch correction given by the observer.]
Totality begins	1	47	0	
Totality ends	1	48	30	
Totality lasts	0	1	30	
Last contact	3	4	58	

From $0^h\ 23^m$ to $1^h\ 48^m$ temperature fell from 60° to 50° Fahr.

Position of station 400 yards E. 25° N. from corner of Sections 5, 6, 7, 8. Elevation about 2,500 feet.

McMahan Ranch, near Davis, Solano County, California.

J. B. Yount, Observer.

The position of the station is defined by the following bearings and distances:

To Davis N. 77° E. $5\frac{1}{2}$ miles; to Dixon S. $15\frac{1}{2}$° W. 5 miles; to Winters N. $77\frac{1}{2}$° W. $5\frac{1}{2}$ miles. The bearings are reduced to the true meridian, allowing $16\frac{1}{2}$° east for the magnetic declination.

The contacts were observed with the telescope of a surveyor's instrument.

First contact	$12^h\ 26^m$
Estimated greatest obscuration	$1^h\ 49^m$ to 1 50
Last contact	3 8

Watch correction not given.

The thermometer at $12^h\ 26^m$ stood at 58°
The thermometer at 12 $49\frac{1}{2}$ stood at 50
The thermometer at 3 8 stood at 56

Several stars were seen. At the time of greatest obscuration the color of the sky was a dull leaden blue.

Nelson, Butte County, California.

A. E. Campe, Observer.

Sketch of the Corona, showing the fish-tail equatorial extension, and general outlines.

Nelson, Butte County, California.

Report of Dr. Lewis Swift, Director of the Warner Observatory, Rochester, New York.

Prof. Edward S. Holden:

Dear Sir: I have the honor to submit to you a report of my observations of the Total Eclipse of January 1, 1889, as observed at Nelson, California, a small place some fifty-five miles north of Sacramento, the Capital of the State. The exact latitude and longitude of my station are unknown to me. For a month before my arrival, there had been a daily rainfall of such proportions as to submerge a large part of the valley, and the prospect of finding a suitable place for mounting my telescope seemed dubious,

indeed. But the rain ceasing, I selected the centre of a vacant square, about one hundred feet south of the hotel and two hundred feet west of the railroad tracks, and set there a stout post with the top sawn off at the proper angle to allow the polar axis of the telescope to lie in the meridian and point approximately to the pole. The telescope was my 4½-inch achromatic, the same one used at the eclipse of 1869 at Mattoon, Ill., and at that of 1878 at Denver, Col., the eyepiece used giving a power of 35, and not 25, as I then supposed.

The principal object of my long westward journey was to, if possible, reobserve the two mysterious objects seen at the Denver eclipse, which, with good reason (as no such were known to exist), were supposed to be intra-Mercurial planets, the circumstantial details of which matter need not be recapitulated here.

In order to obtain the position of any unknown body which might be found, I had attached to the R. A. circle a contrivance precisely similar to that used for several years at the WARNER Observatory for reading directly from the circle the R. A. of an object, and which is described and illustrated in vol. I, page 8, of "History and Work of the WARNER Observatory," which work will be mailed to any person reading this who may desire it, and who will favor me with his address. It was, presumably, the first attempt ever made to accurately determine by direct reading, the R. A. of a body near a totally eclipsed Sun. A brass circle some 10 inches in diameter, supporting, for celerity of reading, a pointer instead of a vernier, was geared to the hour arbor of a clock train regulated to sidereal time. The pointer will, of course, make one revolution around the R. A. circle in 24 sidereal hours, or, in other words, will keep pace with the diurnal motion of the heavens. The R. A. circle, connected by a metallic cord to a pulley on the polar axis, would move as the telescope was moved, and at precisely the same rate. Now, the pointer, if previously set to the R. A. of the Sun or a star, would indicate, at once, the Right Ascension of any object afterwards found. A few minutes before the second contact, the Sun's western limb was brought to the intersection of the cross wires in the positive eyepiece, and the pointer revolved to indicate its R. A. at that time. I had previously instructed two assistants to quickly read when time should be called, one, the R. A., the other the Dec. circle.

On the eventful day of the eclipse the Sun rose clear, inspiring the hope that the sky might remain unclouded through the day,

or at least grant the fulfillment of my ardent desire for unobstructed observation of the great phenomenon during the one hundred and sixteen precious seconds of totality. About the time of first contact a small cloud began to form southeast of the Sun; watching it with great care as well as intense dread, a slow motion towards the Sun was detected, which continued until the Sun was reached, over which it passed at the critical moment of total phase, blotting it out, and with it all hope of refinding the suspected intra-mercurial planets, to which quest I had resolved to devote four fifths of the allotted time.

Just before the commencement of the eclipse, I had set my watch, and Mr. N. B. Scott, who assisted me, his very excellent pocket stop chronometer, to the Lick Observatory time as transmitted to the telegraph office in Nelson. Following are the times of contacts as given by Mr. Scott:

	h	m	sec	
1st contact	12	24	36	Thermometer 56.
2d contact	1	48	29	Thermometer 51.
3d contact	1	50	25.4	Thermometer 51.
4th contact	3	8	14	Thermometer 52.
Duration of totality		1	56.4	
Duration of eclipse	2	43	38	

Baily's Beads.

There has been much speculative writing concerning this singular and, at times, beautiful phenomenon observed at every total and annular eclipse for at least a century. The cause usually assigned is, the shining of the Sun through depressions between lunar mountains, a theory which, when compared with observed facts, has no support. As I saw them in 1878, every one was trapezoidal in shape, and differed in size only, becoming mere points at the ends of the crescent, and increasing gradually and regularly towards its centre. As seen at the California eclipse, they bore not the least resemblance to those just described as seen at Denver. Instead of being trapezium shaped, they resembled (at both second and third contacts) a curved series of dotted "i's," or rather the telegraphic letter a (dot and dash) of the Morse alphabet, thus ·— ·— ·— ·—

Prof. Charles A. Schott says of those seen in 1869: "I would particularly notice their great regularity in width, outline, and distribution." Prof. D. G. Eaton records: "Baily's Beads were very conspicuous. Just before totality the thin crescent was broken by *dark lines shooting out from and perpendicular to the edge of*

the Moon." From these testimonies and from my personal observations, I am irresistibly led to the conclusion that they, like the color of the protuberances, are not seen alike by all observers, and that their true cause has never yet been ascertained. But were I to hazard an opinion, it would be that they are the result of a phenomenon closely allied, if not identical, with that producing the "Black Drop." Quite probably diffraction and irradiation may have much to do with it—possibly may be its sole causes. Were the usually assigned reason the true one, then on the occasion of an annular eclipse, when the Moon so nearly equals the Sun in size as to cause the annulus to be exceedingly narrow, as there are mountains all around the Moon, the beads also should be seen all about it. Again, long before a total phase is reached, the ends of the crescent, all the time reduced to a hair-like fineness, ought to reveal them, which is not the case.

The Prominences.

These were six in number, one on the preceding and five on the following limb of the Moon. All were small and, in comparison to those seen at the eclipse of 1869, very uninteresting objects. That on the preceding limb was the largest of the six, and just above it, a little to the north but entirely detached from both it and the Moon, was a cloud which if called a prominence would increase the number to seven. Their uniformity of shape and size immediately attracted my attention and also the absence of all color. In form I compared them to the short, sharp, conical teeth of a circular saw. It at once occurred to me to watch the uncovering of the one on the west, and the covering up of those on the east limb by the advancing Moon. During totality the five were seen growing steadily shorter and the one as unmistakably growing in length, and, at its close, only the very tips of the saw-teeth-like forms were visible.

*Color of the Protuberances.**

Nothing seen during totality surprised me so much as the color of the protuberant flames, which were as white as burnished silver, while in 1869 and 1878 they had been seen of a dull scarlet color, and I had therefrom supposed that they always were tinted. It really seemed that my eye was deceiving me, so, to satisfy myself whether this were true, I carefully compared them with the Corona, and found them to be precisely the same save that the prom-

* See Tacchini, *Atti d. Accad. dei Lincei*, 1880, p. 472.—E. S. H.

inences were slightly the brighter. In a hasty newspaper report sent out just after the eclipse, I stated that the protuberances were colorless. For this assertion I have been criticized in several quarters. But that they are not always seen of a red color by all observers the following extracts abundantly prove: "At first view," says Prof. STEPHEN ALEXANDER, "they" (the prominences) "were white, and yet, within the few seconds which I could devote to their inspection, these white prominences, portions of them, became tinted with a pale rose color." General HALSTEAD "saw them red with the bare eye, though, afterwards, they appeared white." Prof. HINES, who wears glasses, states that "At the first instant of totality, my eyes were directed to the Moon, and I perceived dazzling white prominences projecting from the Moon. My attention was then attracted to the photographic apparatus, and, after about half a minute, upon looking up, I found the former white prominences of a brilliant, decided rose-color bordering on crimson, and they remained of this color to the end of totality."

Mr. BROWNE says: "As seen with the bare eye, the prominences appeared white bordered with a delicate rose color." Mr. ZENTMAYER last saw them white with a tinge of blue. Mr. MOELLING saw them white all the time. Mr. RICHARD D. CUTTS testifies: "The Corona was of a white light and the protuberances of an intense white light, and clearly visible to the naked eye." Professor CHARLES A. SCHOTT says: "Two of those were separate from the rest, which consisted of two large patches of intensely bright light of a white color, whereas all the other prominences were of a delicate pink." All the foregoing extracts relate to the eclipse of August 7, 1869. I am unable to account for such capricious seeing. At the same eclipse, I, myself, certainly saw the protuberances referred to of a bright red color. The protuberances deserve more attention from astronomers and more study than they have hitherto received. Right here I cannot refrain from an allusion to an observation of my own of the great protuberance—often from a fancied resemblance called the anvil protuberance—at the eclipse of 1869, which, as I was unaware of any other having seen, I supposed until recently was only another instance of abnormal seeing. Many black lines were seen crossing it in different directions, and inasmuch as they must have been, at least, fifty thousand miles long and a thousand miles

broad, it would appear to be important to understand the cause of this phenomenon, and if these markings are always present. Quite lately, in examining reports of that event by different astronomers, I found several corroborative testimonies regarding this appearance. Mr. ALVAN G. CLARK saw radial lines in the large protuberance. Professor GEORGE DAVIDSON, who was stationed in Alaska, relates: "The flames were not of a uniform color, but were marked by dark lines perpendicular to the Moon's limb; on the larger flame these dark lines were very distinct." In all future eclipses I advise careful and particular observation for this phenomenon.

The Corona.

This mysterious phenomenon was observed under so great difficulties, owing to haziness, that I would not venture to pronounce either upon its extent or general contour. The striated filaments were, however, seen as at former eclipses.

Mr. A. E. CAMP, who was stationed three miles north of Nelson, where the sky in the neighborhood of the Sun was clear, made, at my request, a naked-eye drawing, as near to scale as possible, of the Corona, which, judging from my own telescopic observation, I think is sufficiently true to nature to warrant its reproduction.

I had engaged and instructed several spectators to watch for waves of light (shadow bands) passing them, at the instant of totality, but none were observed. On the peaks of the Coast Range to the west, the shadow of the approaching Moon was seen, and also that as it receded over the foothills and mountain peaks of the Sierra Nevada.

The planets *Mercury* and *Venus*, and the stars *Vega* and *Deneb*, were seen.

The people of Nelson were assiduous in their attentions and assistance, and did all in their power to make my observations successful. My thanks are particularly due to Mr. J. S. SHILLING, who prepared and set the post for my telescope and rendered me much mechanical aid. Also to Mr. N. C. KENDALL, the courteous telegraph operator, and to Mr. N. B. SCOTT particularly, who, in giving me the times of the contacts, must have lost most of the sublime phenomena of the eclipsed Sun. Lastly, I cannot refrain from expressing my gratitude to Mr. H. H. WARNER for his kindness and liberality in defraying, in the interest of astronomical science, the entire expense of my journey to the Pacific Coast and

return; nor of commending him to the consideration of astronomers generally as a most munificent patron of Astronomy.

Very truly yours,

LEWIS SWIFT.

WARNER OBSERVATORY, ROCHESTER, N. Y., April 3, 1889.

NORMAN, COLUSA COUNTY, CALIFORNIA. Platform of Railroad Station.*

W. W. BELSHAW, Observer.

The duration of totality was noted by means of a "chronograph" watch, correction not given.

Beginning of totality	$1^h\ 47^m\ 41\frac{3}{8}^s$
End of totality	1 49 38
Duration	1 $56\frac{5}{8}$

A sketch of the Corona was made by the aid of a field glass, showing the fish-tail streamers and polar rays.

NORMAN, COLUSA COUNTY, CALIFORNIA.

JOHN M. GAMBLE, Observer.

A naked-eye drawing of the Corona was made, showing two equatorial streamers on each side of the Sun, about 1½ diameters in length. The clouds near the horizon below the Sun were of a dull, yellowish-pink during totality—the sky opposite the Sun a cold, gray-green.

The duration of totality was observed, using a piece of smoked glass and a watch.

Beginning of totality	$1^h\ 51^m\ 20^s$
End of totality	1 52 39
Duration†	1 19

*The position of this station is about $\varphi=39°\ 24.'5$. $\lambda=8^h\ 8^m\ 45^s$. J. E. K.

†Probably some mistake in recording, as the duration of totality at Norman was about $1^m\ 56^s$.

NORMAN, COLUSA COUNTY, CALIFORNIA.

REPORT OF WILLIAM IRELAND.

Prof. E. S. HOLDEN, *Director Lick Observatory, Mount Hamilton, San José, Cal.:*

SIR: I respectfully submit to you the following report of photographic observations at Norman, Cal., of the Total Solar Eclipse of January 1, 1889, made by myself, assisted by Mr. PIERRE DE STAEL OLNEY and Mr. WILLIAM S. JOYCE, all of Oakland, Cal.

I sent you to-day by WELLS, FARGO & Co.'s Express the result of the observations in the shape of four glass positives, marked 1, 2, B, and D.

The apparatus used was a large portrait lens, WILLARD & Co., New York, No. 7206 (aperture 5⅞ inches, stopped down to 3⅞ inches, *back* focus 20 inches) attached to a plain bellows camera carrying plates 5 by 8 inches, the whole being mounted on a tripod fitted with a screw to adjust the instrument in altitude. I send you also a photograph of the instrument.

The place at which the photographs were taken was a point about 50 feet southerly from the southwest corner of the railroad station at Norman.

Mr. OLNEY capped and uncapped the lens, I drew the slides and counted the seconds, and Mr. JOYCE rendered valuable assistance in transporting the instruments, etc.

During the forenoon the Sun was at intervals hidden by clouds, but at about 1:30 P. M. the clouds dispersed and the narrow crescent of the Sun appeared in a clear sky. There was no wind blowing.

Immediately before totality I pointed the camera towards the Sun and carefully focused it on the visible limb, and laid the plate-holders on a box where they would be easily accessible for rapid work. Each plate-holder carried one slow plate (sensitometer mark, 15), and one rapid (sensitometer mark, 27), and both plates in each holder were given the same exposure.

The moment that totality commenced, I drew the slide of Plate No. 1, and called to Mr. OLNEY to uncap the lens, and, after counting five seconds, called to him to recap, but at this moment the crowd which had gathered about us became very noisy, and it was impossible for Mr. OLNEY to hear the calls, consequently this exposure, which was intended to be five seconds, may have been one or two seconds longer.

The other exposures, as noted below, are practically correct, and are given in the order in which they were made, the last one being completed about ten seconds before the reappearance of the Sun's limb:

Plate.			Exposure.
Number.	Brand.	Sensitiveness.	
1	Cramer—Lightning	15	5 (?) seconds.
2	Carbutt—Eclipse	27	5 seconds.
B	Carbutt—Eclipse	27	1 second.
D	Carbutt—Eclipse	27	10 seconds.

Three other exposures were made, but owing to vibration of the camera the images were badly distorted, so I have not sent you copies of them.

I wish at this time to thank you for the several copies of "Instructions to Observers," which you kindly sent me previous to the eclipse.

Should the negatives of any of the positives sent you be of any use to you, I will be glad to loan them to you if you so request.

Yours respectfully,

WM. IRELAND.

1016 East Twenty-sixth street, Oakland, Cal.
February 11, 1889.

Remarks on Mr. Ireland's Positives.

Plate No. 1 was exposed perhaps a trifle before the photosphere had entirely disappeared, as the limb of the Moon on the eastern side is badly solarized, and surrounded by an aureole due to total reflection from the back of the plate. It is of great interest because it also shows the Corona on the same side of the Moon, and the outlines of the streamers are exactly the same as at the middle of the eclipse. The greatest extension of the Corona on this plate is 63′ from the Moon's centre.

Plate No. 2 shows a somewhat greater extension of the Corona than No. 1. The motion of the image was considerable, and no details appear.

Plate B is much like No. 2.

Plate D shows a remarkable length of the coronal streamers, those on the west reaching as far as 135′ from the Moon's centre. This plate has already been commented upon by Professor HOLDEN. *Mercury* appears on all the positives.

Pennington, Sutter County, California.

Miss Mary Gilliam, Observer.

Few clouds were visible at the beginning of the eclipse, but they formed very rapidly and almost covered the sky during totality. They dissolved on the reappearance of the Sun. No perceptible change of the barometer was noticed. No fog and little, if any, dew was formed. The thermometer fell from 53½° at the beginning of the eclipse to 49° at the end of the total phase, rising to 51° at the end of the eclipse.

San Francisco, California.

Capt. Chas. Goodall, Observer.

The first and fourth contacts were observed with a 6-inch equatorial at a point about one mile S.S.W. of the Davidson Observatory. A greenish shade glass was used.

First contact, watch	$12^h\ 25^m\ 8^s$ (unsatisfactory).
Fourth contact, watch	3 10 54

The Moon's limb could be traced a short distance outside the disc of the Sun.

The watch was compared with Standard Pacific Time at Shreve's jewelry store after the observations, and found to be $2^m\ 0^s$ too fast.

Ukiah, Mendocino County, California.

D. D. Beatty, Observer.

Three negatives of the Corona obtained with a Dallmeyer lens and No. 26 Seed plates. Exposure from 3 to 5 seconds. Inner Corona shown.

Ukiah, Mendocino County, California.

A. O. Carpenter, Observer.

Two photographs were obtained during totality, and several before and after. Prints from the negatives were sent to the Lick Observatory and those of the Corona show a considerable extension. The apparatus is not described.

The negatives were presented to the Observatory, but were unfortunately broken in transmission.

Ukiah, Mendocino County, California.

Mrs. Grace Davis, Observer.

A handsome crayon drawing of the Corona was made, representing very satisfactorily its general appearance to the naked eye.

Winnemucca, Humboldt County, Nevada.

E. P. Austin, Salt Lake City, Utah, Observer.

The first, third, and last contacts were observed with a small telescope, about 2 inches in aperture, magnifying about 8 diameters. The second contact was observed with a large binocular of about the same power as the telescope.

Watch time of first contact	1^h	35^m	26^s	(perhaps 1^s late).
Watch time of second contact	2	56	55	
Watch time of third contact	2	58	42	
Watch time of fourth contact	4	14	0	(possibly 2^s or 3^s early).

Watch correction to Pacific Standard Time = $-1^h\ 2^m\ 12^s.5$, at 0^h January 1, Pacific Standard Time. The rate of the watch was small, not above 4^s per day either way.

The observing station was 240 feet west, and 1,300 feet south of Lieutenant Wheeler's astronomical station, the position of which, as recorded on the monument, is:

Longitude	117° 43′ 54″.18
Latitude	40 58 19 .97

Winnemucca, Humboldt County, Nevada.

J. A. Brashear, Observer.

A drawing was made of the details of the inner Corona, on a specially prepared piece of ground glass. It is described and illustrated in the *Sidereal Messenger* for April, 1889.